PB83-146100

User's Instructions for the SHORTZ and LONGZ Computer Programs. Volume I

H. E. Cramer Co., Inc.
Salt Lake City, UT

Prepared for

Environmental Protection Agency
Philadelphia, PA

Mar 82

U.S. Department of Commerce
National Technical Information Service
NTIS

PB83-146100

USER'S INSTRUCTIONS FOR THE SHORTZ AND LONGZ COMPUTER PROGRAMS

(VOLUME I)

UNBOUND REPRODUCIBLE COPY

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-903/9-82-004a	2.	3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE User's Instructions for the SHORTZ and LONGZ Computer Programs--Volume I	5. REPORT DATE March 1982 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Jay R. Bjorklund and James F. Bowers	8. PERFORMING ORGANIZATION REPORT NO. TR-82-131-01
9. PERFORMING ORGANIZATION NAME AND ADDRESS H. E. Cramer Company, Inc. P. O. Box 8049 Salt Lake City, Utah 84108	10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. Contract No. 68-02-2547, Task Order No. 1
12. SPONSORING AGENCY NAME AND ADDRESS U. S. Environmental Protection Agency, Region III 6th and Walnut Streets Philadelphia, Pennsylvania 19106	13. TYPE OF REPORT AND PERIOD COVERED Final 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES for magnetic tape see PB82-146118
Supersedes H. E. Cramer Company, Inc. Technical Report TR-79-131-01

16. ABSTRACT

The SHORTZ and LONGZ computer programs are designed to calculate the short-term and long-term ground-level pollutant concentrations produced at a large number of receptors by emissions from multiple stack, building and area sources. SHORTZ and LONGZ are applicable in either rural or urban areas of both flat and complex terrain. SHORTZ and LONGZ are written in FORTRAN and are specifically designed for use on a UNIVAC 1110 (or other UNIVAC 1100 series) computer. Both programs require a random-access mass storage device. SHORTZ requires approximately 55K words of core and LONGZ requires approximately 50K words of core. Volume I of the User's Instructions contains a detailed technical discussion of the dispersion-model equations implemented by SHORTZ and LONGZ and detailed user's instructions for the two programs. Volume II contains appendices which include: (1) complete listings of the SHORTZ and LONGZ programs, (2) example SHORTZ and LONGZ problems, (3) coding forms for card input to SHORTZ and LONGZ, (4) discussions of the development and testing of the stack-tip downwash and complex terrain algorithms used by SHORTZ and LONGZ, and (5) a SHORTZ meteorological preprocessor program for use with National Weather Service (NWS) surface and upper-air meteorological data.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air pollution Turbulent diffusion Meteorology Mathematical models Computer models	Dispersion Complex terrain Downwash	

18. DISTRIBUTION STATEMENT Release Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

EPA-903/9-82-004a
March 1982

USER'S INSTRUCTIONS FOR THE SHORTZ AND LONGZ COMPUTER PROGRAMS

(VOLUME I)

by

Jay R. Bjorklund and James F. Bowers

EPA Contract No. 68-02-2547

Task Order No. 1

Project Officer

Alan J. Cimorelli
U. S. Environmental Protection Agency, Region III
Curtis Building
Sixth and Walnut Streets
Philadelphia, Pennsylvania 19106

H. E. Cramer company, inc.
UNIVERSITY OF UTAH RESEARCH PARK
POST OFFICE BOX 8049
SALT LAKE CITY, UTAH 84108

DISCLAIMER

This report was furnished to the Environmental Protection Agency by H. E. Cramer Company, Inc., University of Utah Research Park, P. O. Box 8049, Salt Lake City, Utah 84108, in fulfillment of Contract No. 68-02-2547, Task Order No. 1. The contents of this report are reproduced herein as received from H. E. Cramer Company, Inc. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the Environmental Protection Agency.

ACKNOWLEDGEMENTS

We wish to acknowledge the important contributions to the preparation of this report made by our Project Officer, Mr. Alan J. Cimorelli of the U. S. Environmental Protection Agency (EPA) Region III, who provided us with many helpful comments and suggestions. Also, we wish to thank Mr. Gene Lourimore, our EPA Project Technical Coordinator at the EPA National Computer Center, Research Triangle Park, North Carolina, for his assistance in the installation of the SHORTZ and LONGZ programs on the EPA UNIVAC 1110 computer system.

In addition to the authors, other staff members of the H. E. Cramer Company, Inc. made important contributions to the preparation of this report. We are especially indebted to Mr. William Hargraves for his assistance in writing and documenting the SHORTZ meteorological preprocessor program. All technical illustrations in this report were prepared by Mr. Kay Memmott. The report was typed by Ms. Sarah Barlow, Ms. Cherin Christensen, Ms. Lori Siedenstrang and Ms. Bonnie Swanson.

CAUTIONARY NOTE TO THE SHORTZ/LONGZ USER

The SHORTZ and LONGZ computer programs were specifically written for application on a UNIVAC 1110 (or other UNIVAC 1100 series) computer. Both programs utilize random access mass storage and UNIVAC system features. Thus, the SHORTZ and LONGZ programs cannot be executed without modification on computer systems other than the UNIVAC 1100 series computers. However, the SHORTZ and LONGZ programs can be modified by the user for use on other, comparable computer systems (the IBM 360/370 series, the CDC 6000 series, etc.) with mass storage capability.

The SHORTZ and LONGZ programs implement highly generalized dispersion models that are designed to address a wide variety of source and topographic configurations. Although many of the dispersion model concepts implicit in the SHORTZ and LONGZ programs are similar to the concepts of other models based on the Gaussian plume formulation, several important model concepts are unique to SHORTZ and LONGZ. Consequently, the user is strongly urged to read all of the technical discussion contained in Section 2 before applying SHORTZ or LONGZ to any modeling problem. Failure to adhere to the technical guidance provided in Section 2 can result in serious misapplications of the SHORTZ and LONGZ programs.

EXECUTIVE SUMMARY

HISTORY OF THE SHORTZ AND LONGZ COMPUTER PROGRAMS

The SHORTZ and LONGZ computerized atmospheric dispersion models were originally developed and tested under Task Order No. 1 of EPA Contract No. 68-02-1387 as part of the H. E. Cramer Company's dispersion model analysis of the SO_2 air quality impact of emissions from the major sources located in and adjacent to Allegheny County, Pennsylvania (Cramer, *et al*., 1975). Under Task Order No. 1 of EPA Contract No. 68-05-2547, the H. E. Cramer Company subsequently implemented the SHORTZ and LONGZ computer codes on the EPA UNIVAC 1110 computer at Research Triangle Park, North Carolina, conducted a seminar for EPA meteorologists on the use of the computerized models and provided EPA with a report documenting the models (Bjorklund and Bowers, 1979). Because EPA did not elect to publish the report by Bjorklund and Bowers (1979) at the time of its completion, the H. E. Cramer Company made the report and the SHORTZ and LONGZ computer codes available to the general public at a nominal cost in December 1979. This report is an updated version of the original report by Bjorklund and Bowers (1979). The principal differences between this report and the 1979 report are: (1) the addition of a new SHORTZ meteorological preprocessor program for use with National Weather Service (NWS) surface and upper-air meteorological data (see Appendix I), (2) the correction of minor coding errors in the SHORTZ and LONGZ computer codes, and (3) the conversion of the SHORTZ and LONGZ computer codes from FORTRAN V to UNIVAC ASCII FORTRAN.

CAPABILITIES OF THE SHORTZ AND LONGZ PROGRAMS

The SHORTZ and LONGZ computer programs are designed to calculate the short-term and long-term ground-level pollutant concentrations produced at a large number of receptors by emissions from multiple stack, building and area sources. SHORTZ uses sequential short-term (usually hourly) meteorological inputs to calculate concentrations for averaging times ranging from 1 hour to 1 year, while LONGZ uses statistical wind summaries to calculate long-term (seasonal and/or annual) average concentrations. Because SHORTZ and LONGZ implement the same basic dispersion model concepts, the two programs in combination effectively constitute a single generalized dispersion model. The SHORTZ and LONGZ programs are applicable in areas of both flat and complex terrain, including areas where terrain elevations exceed stack-top elevations. However, the majority of tests of the two programs made using actual emissions, meteorological and air quality data have been in urban and rural areas of complex terrain (see Appendix H). The SHORTZ and LONGZ computer programs are written in FORTRAN and are specifically designed for use on a UNIVAC 1110 (or higher UNIVAC 1100 series) computer. Both programs require a random-access mass storage device. SHORTZ requires approximately 55,000 words of core and LONGZ requires approximately 50,000 words of core.

Table I summarizes the major capabilities and options of the SHORTZ program. SHORTZ accepts any combination of up to 300 stack, building and area sources. The building source option is used to model the impact of low-level emissions from building vents and roof monitors, while the area source option is used to model the impact of either fugitive emissions (for example, wind-blown particulates from an open storage pile) or urban area source emissions (for example, emissions from home heating). The building and area source options can also be used to represent line sources (for example, emissions from roadways). The Cramer, _et al_. (1975) stack-tip downwash correction may be applied to all stack sources or to user-specified stack sources, and the procedures suggested by Cramer, _et al_. (1975) to account for variations in terrain height over the receptor grid may be applied to all source types. SHORTZ is capable of considering the effects on particulate air quality of the gravitational settling and dry deposition of large particles (diameters above about 20 micrometers).* Additionally,

---

*The procedures used by SHORTZ to account for the effects of gravitational settling and dry deposition for particulates with appreciable settling velocities are the same as those used by the Industrual Source Complex (ISC) Dispersion Model (Bowers, _et al_., 1979) with the surface reflection coefficient set equal to zero (_i.e._, all material that comes in contact with the surface is assumed to be retained at the surface).

TABLE I

SUMMARY OF THE MAJOR CAPABILITIES AND OPTIONS OF THE SHORTZ PROGRAM

Ground-level concentration for averaging times of 1 hour to 1 year (maximum of four concentration averaging times in a single run).

Stack, building and area source options (accepts up to 300 sources in any combination of source types).

Cramer, et al. (1975) stack-tip downwash correction as an option for stack sources.

Cramer, et al. (1975) terrain-adjustment procedures for complex terrain (terrain elevations both below and above emission heights).

Effects on ambient particulate concentrations of the gravitational settling and dry deposition of large particles (flat terrain only).

Time-dependent exponential decay of pollutants.

Capability of varying all emissions parameters for each source on an hour-by-hour basis.

Accepts up to 1,800 receptors.

Polar or Cartesian coordinate system for the regular receptor array (if any).

Polar or Cartesian coordinate system for the discrete (arbitrarily placed) receptors (if any).

Preprocessor program for National Weather Service (NWS) meteorological data.

Capability of using onsite meteorological data, including turbulence (wind fluctuation) measurements as direct inputs.

Capability of printing the concentrations calculated for each source and/or for user-specified subsets of sources as well as for all sources.

Capability of updating (adding to, deleting from or modifying) a master source/concentration inventory computer tape.

SHORTZ can consider the effects on air quality of the time-dependent exponential decay of pollutants (for example, the psuedo-first-order transformation of SO_2 to sulfates). For each source, the SHORTZ user may hold all emissions parameters (pollutant emission rate, stack gas flow rate and stack exit temperature) constant or vary any of the parameters on an hour-by-hour basis. SHORTZ accepts a maximum of 1,800 receptors in either a polar or a Cartesian coordinate system. This total includes the regular receptor array (if any) and the discrete (arbitrarily placed) receptors (if any). Although a SHORTZ meteorological processor program exists for use with National Weather Service (NWS) data, SHORTZ is designed to use onsite meteorological data to the maximum extent possible. If onsite measurements of the standard deviations of the wind azimuth and elevation angles are available, these measurements may be substituted for an estimate of the Pasquill stability category and used as direct inputs to SHORTZ. The SHORTZ optional print output includes tables of the concentrations calculated at all receptors for each source and/or for user-specified subsets of sources as well as for all sources combined. The SHORTZ optional tape output, which is similar to the LONGZ optional tape output, is discussed below.

Table II summarizes the major capabilities and options of the LONGZ program. In general, these capabilities and options are identical to those of the SHORTZ program: The exceptions are: (1) LONGZ accepts up to 14,000 sources in any combination of source types, and (2) the LONGZ source and meteorological inputs requirements differ from the SHORTZ source and meteorological input requirements. For each source, the LONGZ user may hold the pollutant emission rate constant or vary the emission rate by: (1) season, (2) wind-speed and stability or time-of-day categories, and (3) season, wind-speed and stability or time-of-day categories. LONGZ uses the average stack gas flow rate and stack exit temperature for each stack source. If NWS meteorological data are used with LONGZ, the principal meteorological inputs are seasonal or annual STAR summaries. (A STAR summary is a statistical tabulation of the joint frequency of occurrence of

TABLE II

SUMMARY OF THE MAJOR CAPABILITIES AND OPTIONS OF THE LONGZ PROGRAM

Long-term (seasonal and/or annual) average concentrations.

Stack, building and area source options (accepts up to 14,000 sources in any combination of source types).

Cramer, et al. (1975) stack-tip downwash correction as an option for stack sources.

Cramer, et al. (1975) terrain-adjustment procedures for complex terrain (terrain elevations both below and above emission heights).

Effects on ambient particulate concentrations of the gravitational settling and dry deposition of large particles (flat terrain only).

Time-dependent exponential decay of pollutants.

Capability of varying the emission rate for each source by season, by the various combinations of wind-speed and stability or time-of-day categories, or by season, wind-speed and stability or time-of-day categories.

Accepts up to 1,800 receptors.

Polar or Cartesian coordinate system for the regular receptor array (if any).

Polar or Cartesian coordinate system for the discrete (arbitrarily placed) receptors (if any).

Capability of using National Climatic Center (NCC) statistical wind summaries (STAR summaries) as meteorological inputs.

Capability of specifying the input format of statistical wind summaries, including the number of wind-direction, wind-speed and stability or time-of-day categories.

Capability of printing the concentrations calculated for each source and/or for user-specified subsets of sources as well as for all sources.

Capability of updating (adding to, deleting from or modifying) a master source/concentration inventory tape.

wind-speed and wind-direction categories, classified according to the Pasquill stability categories.) If onsite meteorological data are used with LONGZ, the user may specify the input format of the statistical wind summaries. For example, the LONGZ user may develop statistical wind summaries for four time-of-day categories (night, morning, afternoon and evening) and determine from the onsite data the median values of other meteorological input parameters (mixing depths, wind-profile exponents, etc.) for the various combinations of wind-speed and time-of-day categories.

All input data and the results of all concentrations calculated by SHORTZ and LONGZ for the averaging time of the input meteorological data may be written to a master source/concentration inventory computer tape for use in future update runs. In general, the SHORTZ meteorological input parameters are hourly averages and the LONGZ meteorological input parameters are seasonal or annual averages. The SHORTZ (LONGZ) master inventory tape may be read by SHORTZ (LONGZ) in subsequent runs to produce concentration tables not printed in the initial run and/or to update the source/concentration inventory contained on the tape. Sources may be added, deleted or altered in update runs using card input for the affected sources. Concentration calculations are then made by SHORTZ (LONGZ) for the affected sources only to obtain an updated estimate of air quality impact without repeating the model calculations for the unaffected sources.

TABLE OF CONTENTS

Section | Title | Page

ACKNOWLEDGEMENTS iii

CAUTIONARY NOTE TO THE SHORTZ/LONGZ USER iv

EXECUTIVE SUMMARY v

LIST OF TABLES xiv

LIST OF FIGURES xvi

1 MODEL OVERVIEW 1-1

1.1 Background and Purpose 1-1
1.2 General Description 1-2
1.3 System Description 1-3

  1.3.1 The Short-Term Model Program SHORTZ 1-3
  1.3.2 The Long-Term Model Program LONGZ 1-4

1.4 Summary of Input Data 1-7

  1.4.1 The Short-Term Model Program SHORTZ 1-7
  1.4.2 The Long-Term Model Program LONGZ 1-11

2 TECHNICAL DESCRIPTION OF THE SHORTZ AND LONGZ COMPUTER PROGRAMS 2-1

2.1 Model Input Data 2-1

  2.1.1 Meteorological Input Data 2-1
  2.1.2 SHORTZ and LONGZ Source Input Data 2-20

2.2 Plume-Rise Formulas 2-24
2.3 The SHORTZ Dispersion Model Equations 2-27

  2.3.1 Stack Emissions 2-27
  2.3.2 Building Source Emissions 2-35
  2.3.3 Area Source Emissions 2-37
  2.3.4 Modification of the Stack, Building and Area Source Models to Account for Gravitational Settling 2-42

2.4 The LONGZ Dispersion Model Equations 2-44

  2.4.1 Stack Emissions 2-44
  2.4.2 Building Source Emissions 2-47
  2.4.3 Area Source Emissions 2-47
  2.4.4 Modification of the Stack, Building and Area Source Models to Account for Gravitational Settling 2-49

TABLE OF CONTENTS (Continued)

Section Title Page

2.5 Application of SHORTZ and LONGZ in Complex Terrain 2-50

2.6 Example Problem 2-58

2.6.1 Example SHORTZ Problem 2-58
2.6.2 Example LONGZ Problem 2-64

3 USER'S INSTRUCTIONS FOR THE SHORT-TERM (SHORTZ) MODEL PROGRAM 3-1

3.1 Summary of Program Options, Data Requirements and Output 3-1

3.1.1 Summary of SHORTZ Program Option 3-1
3.1.2 Data Input Requirements 3-5
3.1.3 Output Information 3-36

3.2 User's Instructions for the SHORTZ Program 3-37

3.2.1 Program Description 3-37
3.2.2 Control Language and Data Deck Setup 3-40
3.2.3 Input Data Description 3-48
3.2.4 Program Output Data Description 3-75
3.2.5 Program Run Time, Page and Tape Output Estimates 3-97
3.2.6 Program Diagnostic Messages 3-103

4 USER'S INSTRUCTIONS FOR THE LONG-TERM (LONGZ) MODEL PROGRAM 4-1

4.1 Summary of Program Options, Data Requirements and Output 4-1

4.1.1 Summary of LONGZ Program Options 4-1
4.1.2 Data Input Requirements 4-5
4.1.3 Output Information 4-37

4.2 User's Instructions for the LONGZ Program 4-38

4.2.1 Program Description 4-38
4.2.2 Control Language and Data Deck Setup 4-41
4.2.3 Input Data Description 4-51
4.2.4 Program Output Data Description 4-81
4.2.5 Program Run Time, Page and Tape Output Estimates 4-110
4.2.6 Program Diagnostic Messages 4-114

5 REFERENCES 5-1

TABLE OF CONTENTS (Continued)

VOLUME II

TABLE OF CONTENTS

Appendix	Title
A	COMPLETE FORTRAN LISTING OF THE SHORT-TERM MODEL (SHORTZ) COMPUTER PROGRAM
B	COMPLETE FORTRAN LISTING OF THE LONG-TERM MODEL (LONGZ) COMPUTER PROGRAM
C	EXAMPLE EXECUTION OF THE SHORT-TERM MODEL (SHORTZ) COMPUTER PROGRAM
D	EXAMPLE EXECUTION OF THE LONG-TERM MODEL (LONGZ) COMPUTER PROGRAM
E	CODING FORMS FOR CARD INPUT TO THE SHORT-TERM MODEL (SHORTZ) COMPUTER PROGRAM
F	CODING FORMS FOR CARD INPUT TO THE LONG-TERM MODEL (LONGZ) COMPUTER PROGRAM
G	DEVELOPMENT OF THE SEMI-EMPIRICAL CORRECTION FACTOR FOR DOWNWASH EFFECTS ON PLUME RISE
H	DEVELOPMENT AND TESTING OF THE CRAMER, *ET AL.* (1975) COMPLEX TERRAIN DISPERSION MODELS
I	THE SHORTZ METEOROLOGICAL PREPROCESSOR PROGRAM

LIST OF TABLES

Number	Title	Page
2-1	Short-Term Meteorological Inputs Required by the SHORTZ Program	2-3
2-2	SHORTZ and LONGZ Default Values for the Wind-Profile Exponent	2-5
2-3	Default Values for Hourly Turbulent Intensities	2-5
2-4	Vertical Potential Temperature Gradients Suggested for Humid and Arid Regions	2-13
2-5	Pasquill Stability Category as a Function of Insolation and Wind speed	2-15
2-6	Insolation Categories	2-15
2-7	Tables of Meteorological Inputs Required by the LONGZ Program	2-16
2-8	Pasquill Stability Categories Approximately Corresponding to the Combinations of Wind Speed and Time of Day	2-19
2-9	Source Inputs Required by the SHORTZ and LONGZ Programs	2-21
2-10	Stack and Emissions Data for the 4 January 1973 Air Pollution Episode at Logans Ferry	2-61
2-11	Meteorological Input Parameters for 4 January 1973	2-62
2-12	Non-Meteorological Inputs for the SHORTZ Example Problem	2-63
2-13	Stack Parameters and Emissions Data for the Hypothetical Aluminum Plant	2-67
2-14	Stack and Particulate Emissions Data for the Hypothetical Aluminum Plant	2-68
2-15	Vertical Turbulent Intensities Used for All Source Types in the Annual Concentration Calculations	2-70
2-16	Mixing-Layer Depths in Meters Used in the Annual Concentration Calculations	2-71

LIST OF TABLES (Continued)

Number	Title	Page
2-17	Ambient Air Temperatures Used in the Annual Average Concentration Calculations	2-73
2-18	Vertical Potential Temperature Gradients in Degrees Kelvin Per Meter Used in the Annual Average Concentration Calculations	2-73
2-19	Wind-Profile Exponents Used in the Annual Average Concentration Calculations	2-74
2-20	Coordinates of Discrete Receptors Placed Around the Property Boundary of the Hypothetical Aluminum Plant	2-75
3-1	Meteorological Data Input Options for SHORTZ	3-2
3-2	Dispersion-Model Options for SHORTZ	3-2
3-3	SHORTZ Output Options	3-4
3-4	Default Values for the SHORTZ Meteorological Parameters	3-27
3-5	SHORTZ Program Card Input Parameters Format and Description	3-50
3-6	SHORTZ Input/Output Tape Format	3-94
3-7	SHORTZ Warning and Error Messages	3-104
4-1	Meteorological Data Input Options for LONGZ	4-2
4-2	Dispersion-Model Options for LONGZ	4-2
4-3	LONGZ Output Options	4-4
4-4	LONGZ Program Card Input Parameters, Format and Description	4-53
4-5	Default Values for the LONGZ Meteorological Parameters	4-78
4-6	LONGZ Input/Output Tape Format	4-107
4-7	LONGZ Warning and Error Messages	4-115

LIST OF FIGURES

Number	Title	Page
1-1	Schematic diagram of the short-term computer program SHORTZ.	1-5
1-2	Schematic diagram of the long-term computer program LONGZ.	1-6
2-1	Mixing depth interpolation schemes for urban and rural areas.	2-10
2-2	Representation of a curved line source by multiple area sources.	2-41
2-3	Mixing depth $H^*_m\{z_s\}$ used to determine whether the stabilized plume is contained within the surface mixing layer.	2-52
2-4	Effective mixing depth $H'_m\{z\}$ assigned to receptors for the concentration calculations.	2-54
2-5	Topographic map of the Springdale-Logans Ferry area.	2-59
2-6	Layout of a hypothetical aluminum reduction facility.	2-65
3-1	Input data deck setup for the SHORTZ program.	3-46
3-2	Example listing of input data for the calculation of hourly, 3-hour and 24-hour ground-level concentration.	3-77
3-3	Example listing of input sources used in the calculation of hourly, 3-hour and 24-hour ground-level concentration.	3-80
3-4	Example listing of the hourly input data.	3-81
3-5	Example listing of a 1-hour ground-level concentration from a single source.	3-82

LIST OF FIGURES (Continued)

Number	Title	Page
3-6	Example listing of 3-hour average ground-level concentration from a single source.	3-84
3-7	Example listing of 24-hour average ground-level concentration from a single source	3-86
3-8	Example listing of 1-hour average ground-level concentration from combined sources.	3-88
3-9	Example listing of 3-hour average ground-level concentration from combined sources.	3-90
3-10	Example listing of 24-hour average ground-level concentration from combined sources.	3-92
4-1	Input data deck setup for the LONGZ program.	4-48
4-2	Example listing of input data for the calculation of seasonal and annual ground-level concentration.	4-82
4-3	Example listing of input sources used in the calculation of seasonal and annual ground-level concentration.	4-95
4-4	Example listing of seasonal ground-level concentration for the winter season due to a single source.	4-97
4-5	Example listing of annual ground-level concentration due to a single source.	4-100
4-6	Example listing of seasonal ground-level concentration for the winter season from combined sources.	4-102
4-7	Example listing of annual ground-level concentration from combined sources.	4-105

(This Page Intentionally Blank)

SECTION 1

MODEL OVERVIEW

1.1 BACKGROUND AND PURPOSE

The SHORTZ and LONGZ computer programs implement the short-term and long-term dispersion models described by Cramer, Geary and Bowers (1975), which were first used in a study for the U. S. Environmental Protection Agency (EPA), Region III of the air quality impact of SO_2 emissions from 107 major stationary sources located in and adjacent to Allegheny County, Pennsylvania. The principal difference between these dispersion models and similar models previously developed by the H. E. Cramer Company, Inc. is the inclusion of new procedures to account for the effects of variations in terrain height over the receptor grid. The SHORTZ and LONGZ computer codes provide the user with the capability to calculate ground-level concentrations produced by a large number of sources at a large number of receptors and to identify the contribution of each source or group of sources to the total concentration calculated for each receptor. Thus, the SHORTZ and LONGZ programs are ideally suited for urban-wide modeling studies, and for all studies involving single or multiple sources located in areas of complex terrain. Although the SHORTZ and LONGZ programs have been used extensively during the past several years in air quality impact studies, detailed documentation and instructions for executing the programs were not made available until December 1979 (Bjorklund and Bowers (1979). The principal differences between this report and the 1979 report are: (1) the addition of a new SHORTZ meteorological preprocessor program for use with National Weather Service (NWS) surface and and upper-air meteorological data (see Appendix I), (2) the correction of minor coding errors in the SHORTZ and LONGZ computer codes, and (3) the conversion of the SHORTZ and LONGZ computer codes from FORTRAN V to UNIVAC ASCII FORTRAN.

The purpose of this report is to provide complete documentation for the SHORTZ and LONGZ computer programs and the SHORTZ meteorological preprocessor program. A detailed description of the dispersion model equations contained in the two programs is given in Section 2. Additionally, Section 2 gives technical guidance on the application of SHORTZ and LONGZ that is based on the H. E. Cramer Company's experience in using the programs in a wide variety of studies during the last six years. Instructions for executing the SHORTZ and LONGZ programs are given in Sections 3 and 4, respectively. Program listings, input data coding forms and example problems are given in the appendices.

We point out that the current versions of the SHORTZ and LONGZ programs described in this report contain some options and features that have been added to the original programs used by Cramer, et al. (1975) in the Allegheny County SO_2 study in order to facilitate their use. However, these additions are peripheral to the main programs containing the basic dispersion-modeling techniques which are the same as those used in the 1975 Allegheny County SO_2 study.

1.2 GENERAL DESCRIPTION

The SHORTZ and LONGZ computer programs are written in FORTRAN and are specifically designed for use on a UNIVAC 1110 computer. Both programs require a random-access mass storage device because both programs automatically assign and allocate mass storage. SHORTZ requires approximately 55,000 words of core and LONGZ requires approximately 50,000 words of core. SHORTZ accepts a maximum of 300 sources and 1,800 receptors, while LONGZ accepts a maximum of 14,000 sources and 1,800 receptors. However, in both programs, the user may increase the limit on the number of sources and decrease the limit on the number of receptors, or vice versa.

The SHORTZ program is designed to use sequential hourly source and meteorological data to calculate ground-level concentration patterns for averaging times of 1 hour to 1 year. Similarly, the LONGZ program is designed to use statistical wind summaries to calculate seasonal and/or annual concentration patterns. Although the SHORTZ program may be used for either short-term or long-term air quality impact analyses, the most efficient procedure is to use SHORTZ to assess short-term impacts and LONGZ to assess long-term impacts.

The SHORTZ and LONGZ computer programs are consistent in all dispersion-model assumptions. Both programs accept the following source types: stack, area and building source emissions. (A building source is defined as a building with emissions at low exit velocity and with minimal thermal buoyancy from vents or short stacks located on or immediately adjacent to the building.) The area source equation in both programs is based on the equation for a continuous and finite crosswind line source. Vertical plume dimensions in both SHORTZ and LONGZ and lateral plume dimensions in SHORTZ are calculated by using turbulent intensities in simple power law expressions that include the effects of the initial source dimensions. The method of image sources is used to account for reflections at the ground surface and at the top of the surface mixing layer. The two programs use the Briggs (1971; 1972) plume-rise equations, modified to include the effects of downwash in the lee of the stack during periods when the wind speed equals or exceeds the stack exit velocity. A wind-profile exponent law is used to account for the variation with height of the wind speed. The effects of gravitational settling and dry deposition on ambient particulate concentrations for particulates with appreciable gravitational settling velocities (diameters greater than about 20 micrometers) are considered using techniques developed by Cramer, et al. (1972). When SHORTZ and LONGZ are applied in complex terrain, the plume axis is assumed to remain at the plume stabilization height and the plume is allowed to mix to the ground as long as the stabilization height is within the surface mixing layer.

1.3 SYSTEM DESCRIPTION

1.3.1 The Short-Term Model Program SHORTZ

Figure 1-1 is a schematic diagram of the short-term model program SHORTZ. As shown by the figure, program control parameters and source data are input by card deck. Meteorological data may be input by a card deck or by the disk file generated by the SHORTZ meteorological preprocessor program described in Appendix I. In general, sequential hourly meteorological data are input to SHORTZ. However, the program will accept any chronologically-ordered, short-term meteorological data. For example, if meteorological data recorded at 3-hour intervals by the National Climatic Center (NCC) are used to develop SHORTZ meteorological inputs, the program will assume that the meteorological inputs represent a 3-hour averaging time. As an option, SHORTZ will store on a master magnetic tape inventory all input data and the results of all concentrations calculated for the assumed averaging time of the input meteorological data. This tape may be read by SHORTZ in subsequent runs to produce concentration tables not printed in the initial run and/or to update the source/concentration inventory on the tape. Sources may be added, deleted or altered in update runs using card input for the affected sources. Concentration calculations are then made for the affected sources only and the concentrations calculated for each source are resummed to obtain an updated estimate of the concentration produced at each receptor by all sources. The SHORTZ optional print output consists of tables of program control parameters, receptor data, source data, meteorological data and the ground-level concentrations calculated for user-specified sources or groups of sources.

1.3.2 The Long-Term Model Program LONGZ

Figure 1-2 is a schematic diagram of the long-term model program LONGZ. As shown by the figure, program control parameters, receptor data, source data and meteorological data are input by card deck. As in the case of SHORTZ, the LONGZ program will, on option, generate a master magnetic tape inventory containing all input data and the results of all concentration calculations. This tape may be read by LONGZ in subsequent runs to produce concentration tables not printed in the initial run and/or to update the source/concentration inventory on

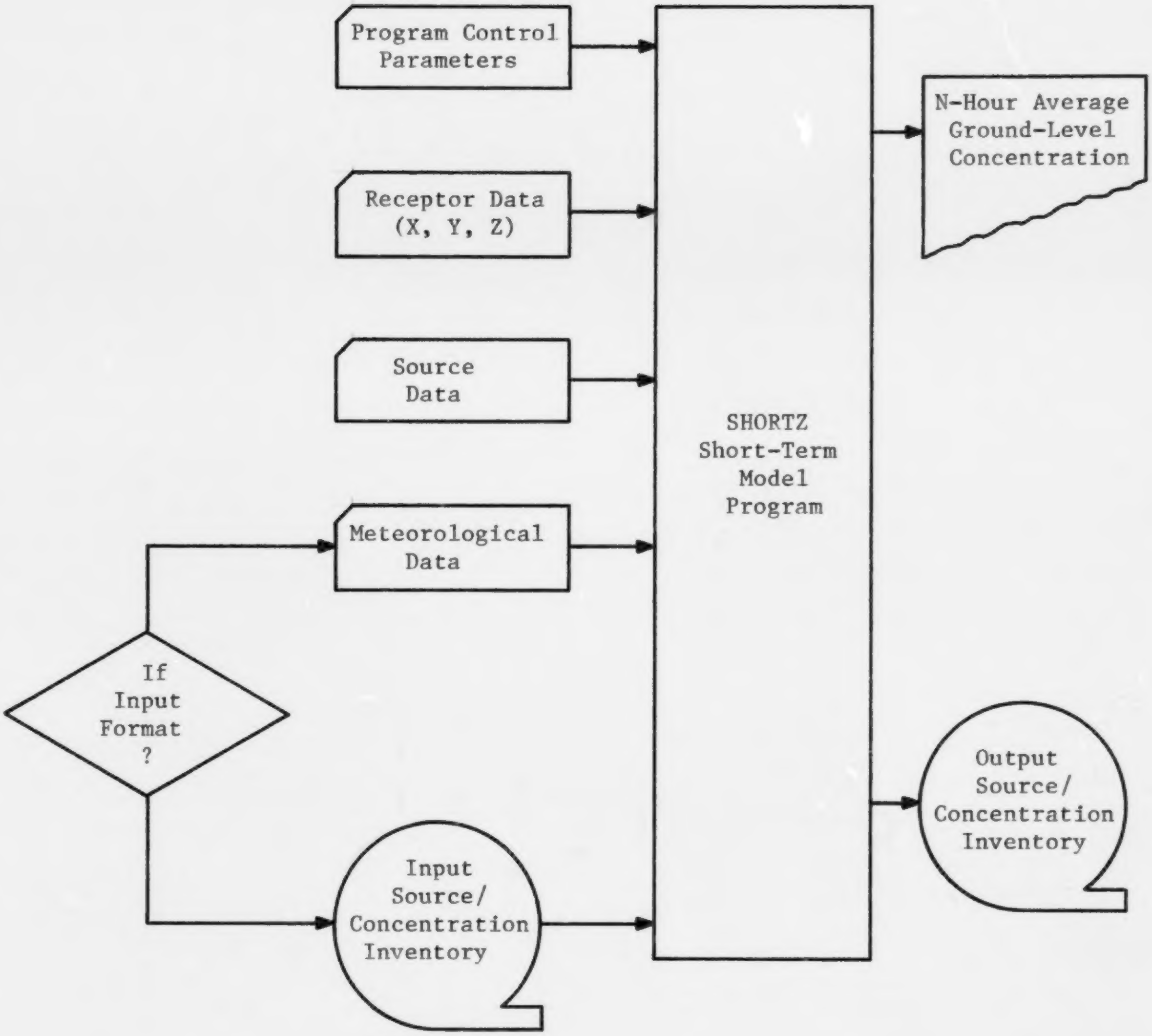

Program Control Parameters
Receptor Data (X, Y, Z)
Source Data
Meteorological Data
If Input Format ?
Input Source/ Concentration Inventory
SHORTZ Short-Term Model Program
N-Hour Average Ground-Level Concentration
Output Source/ Concentration Inventory

FIGURE 1-1. Schematic diagram of the short-term computer program SHORTZ.

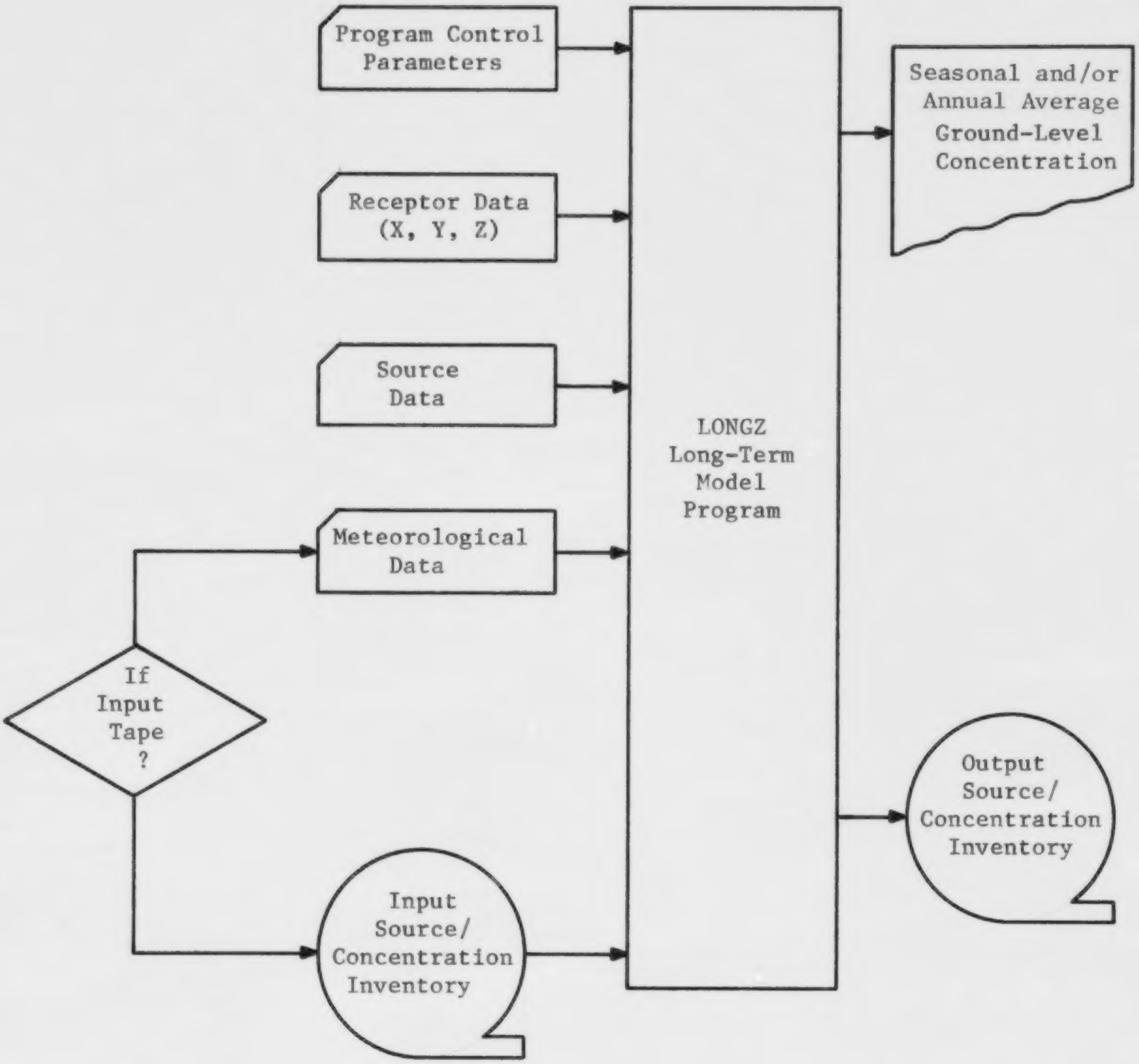

Program Control Parameters
Receptor Data (X, Y, Z)
Source Data
Meteorological Data
If Input Tape ?
Input Source/ Concentration Inventory
LONGZ Long-Term Model Program
Seasonal and/or Annual Average Ground-Level Concentration
Output Source/ Concentration Inventory

FIGURE 1-2. Schematic diagram of the long-term computer program LONGZ.

the tape. The LONGZ and SHORTZ master tape inventory options are especially useful in evaluating compliance with the Prevention of Significant Deterioration (PSD) Regulations when new sources are added and/or existing sources are modified. The LONGZ optional print output consists of tables of program control parameters, receptor data, source data, meteorological data and seasonal and/or annual average ground-level concentrations calculated for user-specified sources or groups of sources.

1.4 SUMMARY OF INPUT DATA

1.4.1 The Short-Term Model Program SHORTZ

The input data requirements for the short-term model program SHORTZ consist of four categories of data:

- Meteorological data
- Source data
- Receptor data
- Program control parameters

Each category is discussed below.

a. Meteorolgical Data Meteorological inputs required by the SHORTZ program include short-term (1-hour average, 2-hour average, 3-hour average, etc.) values of the wind direction, wind speed, ambient air temperature, lateral and vertical turbulent intensities, depth of the surface mixing layer, wind-profile exponent and vertical potential temperature gradient. The program will automaticaly assign wind-profile exponents and turbulent intensities if the Pasquill stability category is input. However, the user is urged to review the default values for these parameters to ensure that they are representative of the area being modeled. The number of hours for which concentration calculations can be made ranges from 1 to 8,784 (*i.e.*, up to every hour of a 366-day year).

b. Source Data. The SHORTZ program accepts three source types: stack, area and building; line sources are simulated by multiple area or building sources. For each source, source data requirements include the source location with respect to a user-specified origin, the source elevation (if terrain effects are to be included in the model calculations) and the pollutant emission rate. For each stack, additional source data requirements include the stack inner radius, the stack volumetric emission rate (i.e., the actual stack gas flow rate) and the stack exit temperature. The horizontal dimensions and effective emission height are required for each area source or building source. If the calculations are to consider particulates with appreciable gravitational settling velocities (particulates with diameters greater than about 20 micrometers), requisite inputs for each source also include the mass fraction of particulates in each gravitational-settling velocity category as well as the settling velocity of each settling-velocity category. Because industrial pollutant emissions are often highly variable, the emission rate for each source and the exit temperature and volumetric emission rate for each stack may be held constant or changed along with each set of meteorological inputs. For example, if 1-hour average meteorological data are input, a different emission rate can be assigned to each source for each hour.

c. Receptor Data. The SHORTZ program uses either a polar (r,θ) or Cartesian (X,Y) coordinate system. Receptor locations in the Cartesian coordinate system may be given as Universal Transverse Mercator (UTM) coordinates or as X (east-west) and Y (north-south) coordinates with respect to a user-defined origin. Discrete receptor points corresponding to the locations of air quality monitors, elevated terrain or other points of interest may also be used with either coordinate system. If the user wishes to use a polar coordinate system in calculations for sources whose locations are entered in UTM coordinates, the user must specify the X and Y UTM coordinates of the desired origin for the polar system. If terrain effects are to be included in the model calculations, the terrain elevation at each receptor point is also required.

d. Program Control Parameters and Options. The SHORTZ program allows the user to select from a number of model options. The program control parameters for these options are discussed in detail in Section 3.2.3. The available options include:

- Receptor Grid System Option -- Selects a Cartesian or a polar receptor grid system
- Discrete Receptor Option -- Allows the user to arbitrarily place a receptor at any point using either a Cartesian or a polar coordinate system
- Receptor Terrain Elevation Option -- Allows the user to specify an elevation for each receptor (level terrain is assumed if this option is not exercised)
- Tape Output Option -- Directs the program to output all input data and the results of all concentration calculations to magnetic tape
- Tape Input Option -- Directs the program to input from magnetic tape all input data from a previous run and the results of all concentration calculations made during the previous run
- Print Input Data Option -- Directs the program to print program control parameters, source data and receptor data; the user may also direct the program to print the meteorological input data
- Output Tables Option -- Specifies up to three averaging times in addition to the averaging time of the input meteorological data for concentration output tables

- Size Options -- Allow the user to specify the number of sources input via data card, the sizes of the X- and Y- axes of receptors (if used), the number of discrete receptor points (if used) and the number of hours in the meteorological input data

- Combined Sources Options -- Allow the user the option of specifying, by source number, multiple sets of sources to use in forming combined sources output or the option of using all sources in forming combined sources output

- Units Option -- Allows the user the option of specifying the input emissions units and/or output concentration units

- Variable Emission Rate Option - Allows the user to assign a constant pollutant emission rate for each source or to assign a new emission rate along with each set of short-term (1-hour average, 2-hour average, etc.) meteorological input parameters

- Print Unit Option -- Allows the user to direct the print output to any output unit

- Tape Unit Option -- Allows the user to select the logical unit numbers of the input and output magnetic tapes

- Turbulent Intensities Option -- Allows the user to enter different turbulent intensities for stacks and for area and building sources

- Rural/Urban Mode Option -- If the Turbulent Intensities Option is not used, directs the program to use the Cramer, et al. (1975) rural or urban turbulent intensities corresponding to the Pasquill stability categories as default values for all source types

1.4.2 The Long-Term Model Program LONGZ

The input data requirements for the long-term model program LONGZ consist of four categories of data:

- Meteorological data
- Source data
- Receptor data
- Program control parameters

Each of these data categories is discussed separately in the following paragraphs.

a. Meteorological Data. Seasonal or annual statistical wind summaries are the principal meteorological inputs to the LONGZ program. In general, these wind summaries are STAR summaries (tabulations of the joint frequency of occurrence of wind-speed and wind-direction categories, classified according to the Pasquill stability categories) with a maximum of six stability categories (A through F). However, LONGZ is also designed to use tabulations of the joint frequency of occurrence of wind-speed and wind-direction categories, subdivided into four time-of-day categories (night, morning, afternoon and evening). Additional LONGZ meteorological data requirements include seasonal average maximum and minimum ambient air temperatures and seasonal median early morning and afternoon mixing depths.

b. Source Data. The LONGZ source data requirements are the same as those given in Section 1.4.1.b for the SHORTZ program.

c. Receptor Data. The LONGZ receptor data requirements are the same as those given in Section 1.4.1.c for the SHORTZ program.

d. Program Control Parameters and Options. The LONGZ program allows the user to select from a number of model and logic options. The program control parameters for these options are discussed in detail in Section 4.2.3. The available options include:

- Receptor Grid System Option -- Selects a Cartesian or polar receptor grid system
- Discrete Receptor Option -- Allows the user to place a receptor at any point using either a Cartesian or polar coordinate system
- Receptor Terrain Elevation Option -- Allows the user to specify an elevation for each receptor (level terrain is assumed by the program if this option is not exercised)
- Tape Input/Output Option -- Directs the program to input and/or output results of all concentration calculations, source data and meteorological data from and/or to magnetic tape
- Print Input Option -- Directs the program to print program control parameters, source data, receptor data and meteorological data
- Print Seasonal/Annual Results Option -- Directs the program to print seasonal and/or annual concentrations, where seasons are normally defined as winter, spring, summer and fall

- Print Unit Option -- Allows the user optionally to direct the print output to any output device

- Tape Unit Option -- Allows the user optionally to select the logical unit numbers used for up to three input and output magnetic tapes

- Size Options -- Allow the user to specify the number of sources input via data card, the sizes of the X- and Y-axes of receptors (if used), the number of discrete receptor points (if used), the number of seasons (or annual only) in the meteorological input data, and the number of wind-speed, Pasquill stability (or time-of-day) and wind-direction categories in the input meteorological data

- Combined Sources Options -- Allow the user to specify, by source number, multiple sets of sources to be used in forming combined sources output or to specify that all sources should be used in forming combined sources output

- Units Option -- Allows the user to specify the input emissions units and/or output concentration units

- Variable Emissions Option -- Allows the user to assign a different emission rate to each seasonal or annual combination of wind-speed and Pasquill stability categories or of wind-speed and time-of-day categories (season is either winter, spring, summer, fall or annual only)

- Turbulent Intensities Option -- allows the user to enter different turbulent intensities for stacks and for area and building sources

- Rural/Urban Mode Option -- If the Turbulent Intensities Option is not used, directs the program to use the Cramer, _et_ _al_. (1975) rural or urban turbulent intensities corresponding to the Pasquill stability categories as default values for all source types

SECTION 2

TECHNICAL DESCRIPTION OF THE SHORTZ AND LONGZ COMPUTER PROGRAMS

This section contains a detailed technical discussion of the SHORTZ and LONGZ computer programs as well as guidance on the application of the programs. For example, Section 2.1 discusses the program input parameters and provides suggestions on how to develop these parameters. Similarly, Section 2.5 discusses the complex terrain adjustment procedures and provides guidance on the application of SHORTZ and LONGZ in complex terrain. *Because of the numerous technical options provided by the SHORTZ and LONGZ programs, the user is strongly urged to read all of Section 2 before applying SHORTZ or LONGZ to any modeling program.*

The general technical guidance contained in this section on the application of the SHORTZ and LONGZ programs is based on the H. E. Cramer Company's experience in performing dispersion-modeling studies using both of these programs and their predecessors. Because each application tends to present a unique combination of source, meteorological and site factors, the specific SHORTZ and LONGZ modeling procedures are best determined on a case-by-case basis after careful consideration of factors such as the representativeness of the available meteorological data, the types of sources to be modeled and the topography of the area. Thus, full utilization of the capabilities of the SHORTZ and LONGZ programs requires that the user have a fundamental knowledge of the concepts of atmospheric turbulence, transport and diffusion.

2.1 MODEL INPUT DATA

2.1.1 Meteorological Input Data

2.1.1.1 SHORTZ Meteorological Input Data

Table 2-1 lists the short-term meteorological input parameters required by the SHORTZ program. In general, the short-term meteorological inputs are for an averaging time of 1 hour. However, data averaged over other time intervals (for example, 2-hour average data) may also be used. The SHORTZ meteorological inputs include the mean wind speed measured at height z_R above the ground, the wind direction (direction from which the wind is blowing), the wind-profile exponent, the standard deviation of the wind-direction angle or lateral turbulent intensity σ'_A, the standard deviation of the wind-elevation angle or vertical turbulent intensity σ'_E, the ambient air temperature, the depth of the surface mixing layer and the vertical potential temperature gradient. Wind speed, wind direction and ambient air temperature are included in airport surface weather observations and in most meteorological tower observations. Additionally, some tower data include measurements of the turbulent intensities. The remainder of the meteorological inputs in Table 2-1 must be developed by the user or by the SHORTZ meteorological preprocessor program contained in Appendix I. This program is specifically designed for use with National Weather Service (NWS) surface and upper-air meteorological data. If representative onsite meteorological measurements are available, we recommend that the SHORTZ meteorological inputs be developed from the onsite measurements (or from a combination of onsite and NWS measurements) rather than from the NWS data. Guidance on the development of SHORTZ meteorological inputs from onsite meteorological measurements is given in the following paragraphs.

Wind-Profile Exponents

SHORTZ assumes that the variation with height of the wind speed in the surface mixing layer is described by a wind-profile exponent law (see Section 2.3). Wind-profile exponents may be calculated from upper-air wind data or from multi-level tower wind data using the logarithmic least-squares regression equation (Brownlee, 1965):

$$p = \frac{N \sum_{i=1}^{N} \left(\ln z_i \ln \bar{u}_i \right) - \left(\sum_{i=1}^{N} \ln z_i \right) \left(\sum_{i=1}^{N} \ln \bar{u}_i \right)}{N \sum_{i=1}^{N} \left(\ln z_i \right)^2 - \left(\sum_{i=1}^{N} \ln z_i \right)^2} \qquad (2\text{-}1)$$

TABLE 2-1

SHORT-TERM METEOROLOGICAL INPUTS REQUIRED BY THE SHORTZ PROGRAM

Parameter	Definition
$\bar{u}_R$	Mean wind speed (m/sec) at height z_R (default value for z_R is 6.1 m)
DD	Mean wind direction (deg) at height z_R
p	Wind-profile exponent (default values assigned on the basis of wind speed and Pasquill stability category)
σ'_A	Wind azimuth-angle standard deviation in radians (default values assigned on the basis of the Pasquill stability category)
σ'_E	Wind elevation-angle standard deviation in radians (default values assigned on the basis of the Pasquill stability category)
T_a	Ambient air temperature (^{o}K)
H_m	Depth of surface mixing layer (m)
$\frac{\partial\theta}{\partial z}$	Vertical potential temperature gradient (^{o}K/m)

where p is the wind-profile exponent, $\bar{u}_i$ is the mean wind speed measured at height z_i, and the summation is over the N values of $\bar{u}$ and z. The wind-profile exponent can be expected to vary from about 0.1 for unstable conditions to about 0.4 for very stable conditions.

In the absence of data to calculate wind-profile exponents, the SHORTZ user may elect to use the program default values, which are assigned on the basis of the wind speed and the Pasquill stability category. Table 2-2 lists the wind-profile exponent default values contained in both the SHORTZ and LONGZ programs. These exponents are principally based on the results obtained by Cramer, et al. (1972) for Dugway Proving Ground, Utah and are consistent with the results obtained by DeMarrais (1959) at Brookhaven National Laboratory. The wind-profile exponents developed for a number of locations by Touma (1977) also support the use of the wind-profile exponents given in Table 2-2. We point out that the entries in Table 2-2 marked with asterisks represent combinations of wind-speed and stability categories that are not allowed to occur according to the Turner (1964) definitions of the Pasquill stability categories. Default values of the wind-profile exponent for these combinations are provided so that the program can be used with other definitions of the Pasquill stability categories which allow these combinations to occur.

Vertical Turbulent Intensities

The equation used by SHORTZ for the standard deviation of the vertical concentration distribution or vertical dispersion coefficient σ_z directly relates σ_z to the vertical turbulent intensity σ'_E (standard deviation of the wind elevation angle in radians) at the effective release height. In the absence of onsite measurements of σ'_E (also equivalent to the standard deviation of the vertical velocity fluctuations σ_w divided by the mean wind speed $\bar{u}$), the default values for σ'_E listed in Table 2-3 are used by both the SHORTZ and LONGZ programs. The σ'_E values for rural areas are based in part on the measurements of Luna and Church (1972) and

TABLE 2-2

SHORTZ AND LONGZ DEFAULT VALUES FOR THE WIND-PROFILE EXPONENT

Pasquill Stability Category	Wind Speed (m/sec)					
	0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	> 10.8
A	0.10	0.10	0.10*	0.10*	0.10*	0.10*
B	0.15	0.10	0.10	0.10*	0.10*	0.10*
C	0.20	0.15	0.10	0.10	0.10	0.10
D	0.25	0.20	0.15	0.10	0.10	0.10
E	0.30*	0.25	0.20	0.15*	0.10*	0.10*
F	0.40	0.30	0.20*	0.15*	0.10*	0.10*

*These combinations of wind-speed and Pasquill stability categories cannot occur according to the Turner (1964) definitions of the Pasquill stability categories.

TABLE 2-3

DEFAULT VALUES FOR HOURLY TURBULENT INTENSITIES

Pasquill Stability Category	σ'_E (rad)		σ'_A (rad)	
	Rural Areas	Urban Areas	Rural Areas	Urban Areas
A	0.1745	0.1745	0.2495	0.2495
B	0.1080	0.1745	0.1544	0.2495
C	0.0735	0.1080	0.1051	0.1544
D	0.0465	0.0735	0.0665	0.1051
E	0.0350	0.0465	0.0501	0.0665
F	0.0235	0.0465	0.0336	0.0665

are consistent with the σ'_E values implicit in the vertical expansion curves presented by Pasquill (1961). In order to accounts for the effects of surface roughness elements and heat sources, the default σ'_E values for urban areas are for the stability category one step more unstable than the indicated stability category. Although both SHORTZ and LONGZ are designed to accept separate turbulent intensities for stacks and for area and building sources, we recommend that only one set of turbulent intensities be used in model calculations for multiple sources with different release heights. The reasons for this recommendation are given below in the discussion of lateral turbulent intensities.

Lateral Turbulent Intensities

The equation used by SHORTZ for the standard deviation of the lateral concentration distribution or lateral dispersion coefficient σ_y is a simple power-law expression that directly relates σ_y to the lateral turbulent intensity σ'_A (standard deviation of the wind azimuth angle in radians) for the averaging time of the input meteorological data. In the absence of onsite measurements of σ'_A, the default values for the hourly lateral turbulent intensity given in Table 2-3 are used by the SHORTZ program. In accord with the measurements of Luna and Church (1972) and others, the default turbulent intensities assume that σ'_A and σ'_E are approximately equivalent for a 10-minute averaging time at heights above the surface of 100 meters or more and that the $t^{1/5}$ law of Osipov (1972) and others can be used to extend σ'_A to longer averaging times. That is, the 1-hour σ'_A values in Table 2-3 were obtained by multiplying the corresponding σ'_E values by 1.43 ($6^{1/5}$). Similarly, 2-hour σ'_A values may be obtained by multiplying the corresponding σ'_E values by 1.64 ($12^{1/5}$).

Cramer (1976) and others have suggested that the appropriate turbulent intensities for use in diffusion model calculations are the turbulent intensities at the effective release height. Because turbulent intensities are rarely measured at the effective release height, Cramer

(1976) also gives simple empirical expressions for the height dependence of the turbulent intensities. The SHORTZ and LONGZ computer programs are designed to account in part for the height variation of turbulent intensities by allowing the user to assign separate values to the upper-level (stack) and lower-level (building and area) sources. However, in the case of multiple sources with different emission heights, we recommend that a single set of turbulent intensities be used for all sources for two reasons. First, lateral plume expansion is independent of emission height at downwind distances where the plume has become uniformly mixed in the vertical. Second, it has been our experience that the turbulent intensities in Table 2-3 are representative of mean values within the surface mixing layer. It is important to note that the turbulent intensities given in Table 2-3 for rural and urban areas are the values suggested by Cramer, et al. (1975) as part of the Allegheny County SO_2 study.

In order to execute the SHORTZ program in a rural or urban mode when no onsite turbulence measurements are available, the user must input appropriate turbulent intensities. As noted above, the turbulent intensities given in Table 2-3 for rural areas are generally assumed to apply for all source types in rural areas. Similarly, the turbulent intensities for urban areas are usually assumed to apply for all source types in urban areas (note that the E and F stability categories are effectively combined in the urban mode). In rural areas of complex or rolling terrain, the urban turbulent intensities in Table 2-3 may be more representative than the rural turbulent intensities because of the effects of terrain roughness or mechanical turbulence.

Mixing Depths

The height of the top of the surface mixing layer is defined as the height at which the vertical turbulent intensity is of the order of 0.01 or smaller. This definition of the height of the top of the surface mixing layer as a function of the vertical turbulent intensity differs significantly from the definition of the mixing height as a function of thermal stratification alone. For example, the mixing heights generated by the meteorological preprocessor program for the Single Source (CRSTER) Model (EPA, 1977) are not appropriate for use with SHORTZ because they are based on thermal stratification alone and do not address mechanical turbulence. Because measurements of the vertical profile of the intensity of turbulence are not generally available, the depth of the surface mixing layer is usually estimated from vertical wind and temperature profiles or from acoustic radar data. In the simplest case, the base of an elevated inversion layer is taken to be the top of the surface mixing layer. It is important to recognize that, with a surface-based inversion, the depth of the surface mixing layer is greater than zero because of the presence of surface roughness elements and, in industrial or urban areas, the presence of heat sources (see Pasquill, 1974, p. 379).

We recommend that the SHORTZ user examine the vertical profiles of wind speed, wind direction, temperature and dew point temperature or humidity to estimate the depth of the surface mixing layer. In the case of a surface-based inversion with no obvious indicator of the top of the mixing layer, one approach is to use Equation (5) in the paper by Benkley and Schulman (1979) to calculate the mechanical component of the mixing depth. (Equation (2-2) below is based on the equation suggested by Benkley and Schulman.) A second, less objective, approach is to set the minimum mixing depth equal to about 2.5 times the average height of the largest roughness elements (trees, buildings, etc.) in the area of concern. In this approach, the roughness elements of the source itself and/or of the urban area can thus be used to infer the minimum mixing depth attributable to mechanical turbulence. Following this procedure, a typical minimum mixing depth in the vicinity of a large industrial source complex or in an urban area is on the order of 100 meters.

The hypothesis that the minimum depth of the surface mixing layer extends to about 2 to 2.5 times the height of the surface roughness elements in the area is based upon the concept that the region of disturbed air flow extends to about 2 to 2.5 times the height of the obstruction to air flow. According to the Technical Support Document for Determination of Good Engineering Practice Stack Height (EPA, 1978 p. 7), this rule "... was probably originally deduced by Sir David Brunt from W. R. Morgan's study of the height of disturbances over a ridge in connection with an investigation into the disaster of an airship." The EPA document also notes that, "No matter what the origins of the rule may be, it can be called a reasonable working rule that is extensively referenced and generally supported by scientific literature." In addition to the wind tunnel studies of the disturbances of the air flow by model buildings and terrain cited in the EPA document, wind tunnel studies of the air flow within and above model crops also indicate that the disturbed flow extends to about twice the height of the canopy (for example, see Plate and Quraishi, 1965, p. 404). It is important to note that the minimum mixing depth within a deep valley with down-valley winds is determined by the height of the roughness elements within the valley and not by the height of the valley walls because the air flow tends to follow the grain of the terrain and does not cross ridge lines.

If mixing depths are obtained from upper-air soundings made less frequently than at 1-hour intervals, an interpolation procedure is required to obtain mixing depths for the intervening hours. Also, we recognize that some SHORTZ users may wish to use sequential hourly surface weather observations with twice-daily mixing depths obtained using the Holzworth (1972) procedures to calculate ground-level concentrations for every hour of the year. Because it is impractical to develop manually the hourly meteorological inputs for each hour in a year, we have developed a SHORTZ meteorological preprocessor program (see Appendix I) which is similar to the meteorological preprocessor program for the standardized short-term dispersion models of the U. S. Environmental Protection Agency (EPA), but which is also consistent with the model concepts upon which the SHORTZ and LONGZ programs are based. Figure 2-1 illustrates the mixing depth interpolation schemes used by the preprocessor program for urban and rural areas. The

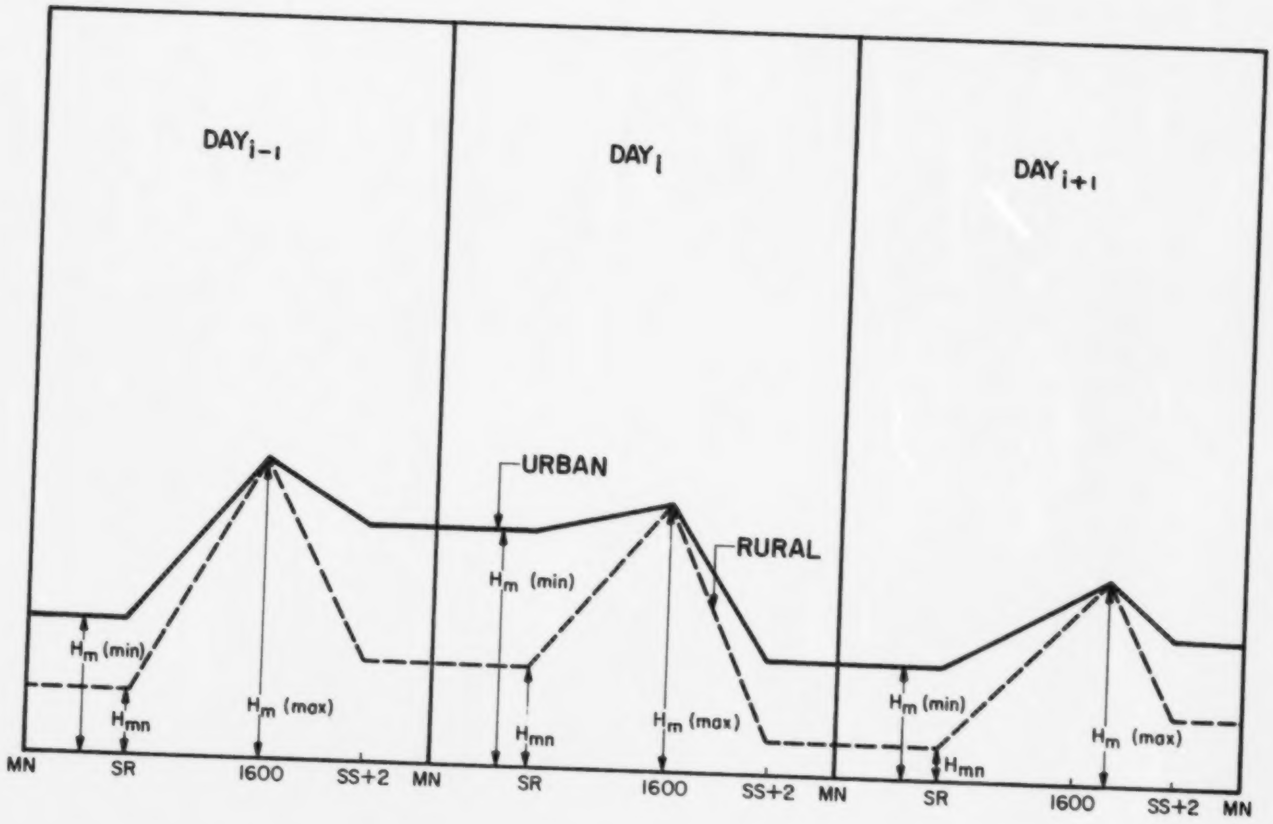

DAY$_{i-1}$
DAY$_{i}$
DAY$_{i+1}$
URBAN
RURAL
H$_m$ (min)
H$_{mn}$
H$_m$ (max)
H$_m$ (min)
H$_{mn}$
H$_m$ (max)
H$_m$ (min)
H$_{mn}$
H$_m$ (max)
MN
SR
1600
SS+2
MN
SR
1600
SS+2
MN
SR
1600
SS+2
MN

FIGURE 2-1. Mixing depth interpolation schemes for urban (solid line) and rural (dashed line) areas used by the SHORTZ meteorological preprocessor program (see Appendix I).

urban scheme, which is shown by the solid line, is based on Holzworth early morning (H_m (min)) and afternoon (H_m (max)) mixing depths. The early morning mixing depth is assumed to apply from sunset plus 2 hours (SS+2) on the preceding day until sunrise (SR); mixing depths for the hours between sunrise and 1600 local standard time (LST), when the afternoon mixing depth is assumed to apply, are obtained by linear interpolation; and mixing depths for the hours between 1600 LST and sunset plus 2 hours, when the early morning mixing depth for the following day is assumed to apply, are also obtained by linear interpolation. The rural mixing depth interpolation scheme, which is shown by the dashed line in Figure 2-1, is identical to the urban scheme except that a rural nighttime mixing depth H_{mn} is substituted for the Holzworth early morning mixing depth. Based on the suggestions of Benkley and Schulman (1979) for calculating the mechanical component of the mixing depth, H_{mn} in meters is given by

$$H_{mn} = \left\{ \begin{array}{ll} a\,\bar{u}_n & ;\ a\,\bar{u}_n \le H_m\ (\mathrm{min}) \\ \\ H_m\ (\mathrm{min}) & ;\ a\,\bar{u}_n > H_m\ (\mathrm{min}) \end{array} \right\} \qquad (2\text{-}2)$$

where $\bar{u}_n$ is the mean wind speed in meters per second (measured at or near a height of 10 meters) during the hours between sunset plus 2 hours on the preceding day and sunrise, and the constant a is a function of the local roughness length z_o. A typical value for a is 100, the default value used in the SHORTZ meteorological preprocessor program. Based on the validation study described by Benkley and Schulamn (1979), site-specific values of a can be calculated from their Equation (5) with the constant 0.185 replaced by 0.133. Inspection of Equation (2-2) and Figure 2-1 shows that rural mixing depth is never allowed to exceed the urban mixing depth.

Vertical Potential Temperature Gradients

The SHORTZ program does not contain any default values for the vertical potential temperature gradient, which is given by

$$\frac{\partial\theta}{\partial z}\ (^\circ K/m) = \frac{\partial T}{\partial z}\ (^\circ K/m) + 0.01 \qquad (2\text{-}3)$$

where $\partial T/\partial z$ is the vertical temperature gradient. The vertical temperature gradient, and hence the vertical potential temperature gradient, may be estimated from rawinsonde or tower data. However, the user is cautioned that temperature gradients obtained from tower measurements frequently are not representative of the average temperature gradients through the surface mixing layer. On the basis of the Turner (1964) and Pasquill (1961) definitions of the Pasquill stability categories, the measurements of Luna and Church (1972), and the previous experience of the H. E. Cramer Company, we suggest the use of the vertical potential temperature gradients in Table 2-4 for humid regions (for example, southwestern Pennsylvania) and for arid regions (for example, southeastern Utah). (The vertical potential temperature gradients in Table 2-4 are used by the SHORTZ meteorological preprocessor program described in Appendix I.) We point out that, if adequate onsite data are available, the onsite measurements of the vertical potential temperature gradient should be used in preference to the values given in Table 2-4.

Pasquill Stability Categories

The SHORTZ program precludes the need for specifying discrete stability categories by using direct turbulence measurements (σ'_A and σ'_E) to calculate plume growth. If onsite measurements of only σ'_A or σ'_E are available, the second turbulence parameter can be estimated from the approximate relationship that the hourly σ'_A value is 1.43 times the corresponding hourly σ'_E value (see the above discussion of lateral turbulent intensities). If no direct turbulence measurements are available, it is necessary to relate turbulent intensities and some of the other SHORTZ inputs to objectively determined stability categories. Consequently, the H. E. Cramer company has developed sets of SHORTZ inputs, listed in Tables

TABLE 2-4

VERTICAL POTENTIAL TEMPERATURE GRADIENTS SUGGESTED FOR HUMID AND ARID REGIONS

Pasquill Stability Category	Wind Speed (m/sec)					
	0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	> 10.8
	(a) Humid Regions					
A	0.000	0.000	0.000*	0.000*	0.000*	0.000*
B	0.000	0.000	0.000	0.000*	0.000*	0.000*
C	0.000	0.000	0.000	0.000	0.000	0.000
D	0.015	0.010	0.005	0.003	0.003	0.003
E	0.030*	0.020	0.015	0.010*	0.003*	0.003*
F	0.035	0.025	0.015*	0.010*	0.003*	0.003*
	(b) Arid Regions					
A	0.000	0.000	0.000*	0.000*	0.000*	0.000*
B	0.000	0.000	0.000	0.000*	0.000*	0.000*
C	0.000	0.000	0.000	0.000	0.000	0.000
D	0.020	0.010	0.005	0.000	0.000	0.000
E	0.030*	0.020	0.010	0.005*	0.000*	0.000*
F	0.040	0.030	0.020*	0.010*	0.005*	0.000*

*These combinations of wind-speed and Pasquill stability categories cannot occur according to the Turner (1964) definitions of the Pasquill stability categories.

2-2 through 2-4, that correspond to the Pasquill stability categories as defined by Turner (1964). Because the SHORTZ inputs in Tables 2-2 through 2-4 are based on the Turner definitions of the Pasquill stability categories, the use of any other scheme to determine the Pasquill stability category may lead to erroneous SHORTZ inputs.

Tables 2-5 and 2-6 summarize the Turner (1964) definitions of the Pasquill stability categories. The wind speeds in Table 2-5 are in knots because airport surface wind speeds are reported to the nearest knot by the NWS, and Turner's classification is based on this convention. The thermal stratifications represented by the various Pasquill stability categories are:

- A - Extremely unstable
- B - Unstable
- C - Slightly unstable
- D - Neutral
- E - Stable
- F - Very stable

2.1.1.2 LONGZ Meteorological Input Data

Table 2-7 lists the tables of meteorological inputs required by the LONGZ program. These inputs include seasonal or annual statistical wind summaries; the average wind speed in each wind-speed category; the wind-profile exponent, vertical turbulent intensity and vertical potential temperature gradient for each combination of wind-speed and stability or time-of-day categories; and the average ambient air temperature and

TABLE 2-5

PASQUILL STABILITY CATEGORY AS A FUNCTION OF INSOLATION AND WIND SPEED

Wind Speed (knots)	Insolation Index						
	4	3	2	1	0	-1	-2
0, 1	A	A	B	C	D	F	F
2, 3	A	B	B	C	D	F	F
4, 5	A	B	C	D	D	E	F
6	B	B	C	D	D	E	F
7	B	B	C	D	D	D	E
8, 9	B	C	C	D	D	D	E
10	C	C	D	D	D	D	E
11	C	C	D	D	D	D	D
$\geq$ 12	C	D	D	D	D	D	D

TABLE 2-6

INSOLATION CATEGORIES

Insolation Category	Insolation Index
Strong	4
Moderate	3
Slight	2
Weak	1
Overcast < 7000 feet (day or night)	0
Cloud Cover > 4/10 (night)	-1
Cloud Cover $\leq$ 4/10 (night)	-2

TABLE 2-7

TABLES OF METEOROLOGICAL INPUTS
REQUIRED BY THE LONGZ PROGRAM

Parameter/Table	Definition
$f_{i,j,k,\ell}$	Frequency distribution of wind-speed and wind-direction categories by stability or time-of-day categories for the ℓ^{th} season
$\bar{u}\{z_R\}_i$	Mean wind speed (m/sec) at height z_R for the i^{th} wind-speed category (default values assume the standard STAR summary wind-speed categories)
$p_{i,k}$	Wind-profile exponent for the i^{th} wind-speed category and k^{th} stability or time-of-day category (default values assigned on the basis of wind speed and Pasquill stability category)
$\sigma'_{E;i,k}$	Standard deviation of the wind-elevation angle in radians for the i^{th} wind-speed category and k^{th} stability or time-of-day category (default values assigned on the basis of the Pasquill stability category)
$T_{a:k,\ell}$	Ambient air temperature (^oK) for the k^{th} stability or time-of-day category and ℓ^{th} season
$\left(\frac{\partial\theta}{\partial z}\right)_{i,k}$	Vertical potential temperature gradient ($^oK/m$) for the i^{th} wind-speed category and k^{th} stability or time-of-day category
$H_{m,i,k,\ell}$	Median surface mixing depth (m) for the i^{th} wind-speed category, k^{th} stability or time-of-day category and ℓ^{th} season

median mixing depth for each seasonal or annual combination of wind-speed and stability or time-of-day categories. The LONGZ default values for the wind-profile exponents and the vertical turbulent intensities are the same as those given for the SHORTZ program in Tables 2-2 and 2-3, respectively. Additionally, the default values for the mean wind speed in each wind-speed category correspond to the standard wind-speed categories used by the National Climatic Center's STAR computer program. With these exceptions, all LONGZ meteorological inputs must be entered by the user. These are two general approaches for developing the tables of LONGZ meteorological inputs, depending on whether STAR or time-of-day wind summaries are used. Each approach is briefly discussed below.

LONGZ is designed to accept STAR summaries with six Pasquill stability categories (A through F) or five stability categories (A through E with the E and F categories combined). If sufficient onsite data are available, the user may follow procedures similar to those discussed in Section 2.1.1.1 to develop median vertical turbulent intensities, wind-profile exponents, mixing depths and vertical potential temperature gradients as well as average ambient air temperatures for use in the model calculations. In the absence of onsite measurements, the inputs given in Tables 2-2 through 2-4 may be used to assign all meteorological inputs except the mixing depths and ambient air temperatures. In the case of an urban area, we suggest that the tabulations of daily observations of the depth of the surface mixing layer, developed using the Holzworth (1972) procedures, be analyzed in order to determine seasonal median early morning and afternoon mixing depths for each wind-speed category. We also suggest that the resulting median afternoon mixing depths be assigned to the A, B and C stability categories; the median early morning mixing depths be assigned to the E and F stability categories; and the averages of the early morning and afternoon mixing depths be assigned to the D stability category. Similar procedures are recommended for assigning mixing depths in rural areas except that the early morning mixing depths for the E and F stability categories should probably be redefined as 2.5 times the height of the largest surface roughness elements in the area or be calculated for each wind-speed category using Equation (2-2). Finally, we suggest for both rural and urban areas that the seasonal average daily maximum temperatures be assigned to the unstable (A, B and C) categories, the seasonal average daily minimum temperatures be assigned to the stable (E and F) categories, and the seasonal average temperatures be assigned to the neutral D category.

The four time-of-day categories that may be used by LONGZ as a substitute for the Pasquill stability categories are defined as follows:

- Morning - Sunrise plus 1 hour to sunrise plus 5 hours
- Afternoon - Sunrise plus 5 hours to sunset minus 1 hour
- Evening - Sunset minus 1 hour to sunset plus 2 hours
- Night - Sunset plus 2 hours to sunrise plus 1 hour

If sufficient onsite data are available, the LONGZ user should develop median vertical turbulent intensities, wind-profile exponents, vertical potential temperature gradients and mixing depths as well as average ambient air temperatures that correspond to the various combinations of wind-speed and time-of-day categories. In the absence of onsite measurements, Table 2-8 gives the Pasquill stability categories that approximately correspond to the various combinations of wind-speed and time-of-day categories (Cramer and Bowers, 1976). On the basis of the relationships between the Pasquill stability categories and the combinations of wind-speed and stability categories given in Table 2-8 plus the inputs given in Tables 2-2 through 2-4, the user may assign all meteorological inputs except mixing depths and ambient air temperatures following the procedures

TABLE 2-8

PASQUILL STABILITY CATEGORIES APPROXIMATELY CORRESPONDING TO THE COMBINATIONS OF WIND SPEED AND TIME OF DAY

Time of Day	Wind Speed (m/sec)					
	0.0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	> 10.8
Night	E	E	E	D	D	D
Morning	C	D	D	D	D	D
Afternoon	B	B	C	C	D	D
Evening	E	E	D	D	D	D

outlined above for STAR summaries. In urban areas, we recommend that the Holzworth seasonal median early morning mixing depths be assigned to the night time-of-day category; the seasonal median afternoon mixing depths be assigned to the afternoon time-of-day category; and the averages of the seasonal early morning and afternoon mixing depths be assigned to the transition (morning and evening) periods. Similar procedures are recommended for assigning mixing depths in rural areas except that 2.5 times the height of the largest surface roughness elements in the area probably should be substituted for the early morning mixing depths with surface wind speeds below about 5 meters per second. Alternately, Equation (2-2) can be used with the mean wind speed in each wind-speed category to calculate nighttime mixing depths. Finally, we recommend that the seasonal average daily maximum temperatures be assigned to the afternoon time-of-day category, the seasonal average daily minimum temperature be assigned to the night time-of-day category, and the seasonal average temperature be assigned to the transition categories.

2.1.2 SHORTZ and LONGZ Source Input Data

Table 2-9 lists the source input parameters required by the SHORTZ and LONGZ computer programs. As shown by the table, there are three source types: stack, building and area. Multiple area or building sources are used to simulate line sources. Source parameters required for each source type include the pollutant emission rate, the source coordinates with respect to a user-specified origin and -- if terrain effects are to be included in the calculations -- the elevation of the source above mean sea level (MSL). Either Cartesian or polar coordinates may be used to reference source locations. If the Universal Transverse Mercator (UTM) coordinate system is used to define receptor locations, UTM coordinates are also used to define source locations. The user may enter a decay coefficient ψ if the pollutant is depleted by any process that can be described by time-dependent exponential decay. The parameters ϕ_n and V_{sn} are only required if concentration calculations are being made for particulates with appreciable gravitational settling velocities

TABLE 2-9

SOURCE INPUTS REQUIRED BY THE SHORTZ AND LONGZ PROGRAMS

Parameter	Definition
Stacks	
Q	Pollutant emission rate (mass per unit time)
ψ	Pollutant decay coefficient (sec^{-1})
X, Y	X and Y coordinates of the stack (m)
z_s	Elevation above mean sea level of the base of the stack (m)
h	Stack height (m)
V	Actual volumetric emission rate (m^3/sec)
T_s	Stack exit temperature (°K)
r	Stack inner radius (m)
ϕ_n	Mass fraction of particulates in the nth settling-velocity category
V_{sn}	Gravitational settling velocity for particulates in the nth settling-velocity category (m/sec)
Building Sources	
Q	Same definition as for stacks
ψ	Same definition as for stacks
X, Y	X and Y coordinates of the center of the building (m)
z_s	Elevation above mean sea level of the base of the building (m)
h	Building height (m)
L	Building length (m)

TABLE 2-9 (Continued)

Parameter	Definition
Building Sources (Continued)	
W	Building width (m)
δ	Angle measured clockwise between north and the long side of the building (deg)
ϕ_n	Same definition as for stacks
V_{sn}	Same definition as for stacks
Area Sources	
Q	Same definition as for stacks
ψ	Same definition as for stacks
X, Y	X and Y coordinates of the center of the area source (m)
z_s	Elevation above mean sea level of the area source (m)
h	Characteristic vertical dimension of the area source (m)
L	Length of the area source (m)
W	Width of the area source (m)
δ	Angle measured clockwise between north and the long side of the area source (deg)
ϕ_n	Same definition as for stacks
V_{sn}	Same definition as for stacks

(diameters greater than about 20 micrometers). Particulate emissions from each source may be divided by the user into a maximum of 20 gravitational settling categories. SHORTZ emission rates may be held constant or may be changed with each set of short-term meteorological inputs. Similarly, LONGZ emission rates may be held constant or may be varied by season or by the combinations of wind-speed and stability or time-of-day categories.

Additional source input data requirements for stacks include the physical stack height, the actual volumetric emission rate (product of the stack exit velocity and the area of the emission point), the stack inner radius and the stack exit temperature. As discussed in Section 2.2, the stack radius is used to calculate the effects of stack-tip downwash on buoyant plume rise. The stack radius for a source should be set equal to zero if the user wishes to delete stack-tip downwash effects from the model calculations. For an area source or a building source, the dimensions of the source and the orientation of the source's long side with respect to true north are entered in place of the stack exit temperature, volumetric emission rate and radius. A building source is defined as a building with emissions at low exit velocity and with minimal thermal buoyancy from vents or short stacks located on or immediately adjacent to the building.

It is important to note that the length of a building or area source should not be more than about twice the source's width because of the procedures used by the SHORTZ and LONGZ programs to calculate concentrations for these source types. SHORTZ rotates the source through the minimum angle that will make either the source's length or width normal to the wind direction. On the other hand, LONGZ approximates a building or area source by a circle with the same horizontal area as the source. Consequently, if the length of a building or area source is more than twice the width, the source should be divided into additional sources in order to maintain computational accuracy. The best results are obtained if sufficient subsources are used so that the length and width of each subsource are approximately equal.

2.2 PLUME-RISE FORMULAS

The plume-rise equations used by the SHORTZ and LONGZ computer programs are based on the Briggs (1971; 1972) equations, modified on the basis of the H. E. Cramer Company's experience in modeling stack emissions. The plume-rise equations do not explicitly include momentum effects for the following reasons: (1) Momentum effects on final plume rise for a buoyant plume are negligible; (2) Momentum effects on final plume rise for a buoyant plume are implicitly included in the empirical entrainment coefficients; and (3) Non-buoyant emissions are usually associated with building sources (see Section 2.3.2). The plume-rise equations used by the SHORTZ and LONGZ programs also assume that final plume rise is attained at the location of the stack. This assumption does not affect the results of the calculations unless the stack is located in complex terrain and a significant terrain feature is located within about ten stack heights from the stack.

The effective stack height H of a buoyant plume is given by the sum of the physical stack height h and the buoyant plume rise Δh. For an adiabatic atmosphere (vertical potential temperature gradient equal to zero) or an unstable atmosphere (vertical potential temperature gradient less than zero), the buoyant plume rise is given by

$$\Delta h_N = \left[\frac{1}{\bar{u}\{h\}} \left(\frac{3F}{2\gamma_1^2} \right)^{1/3} (10h)^{2/3} \right] f \qquad (2\text{-}4)$$

where the expression in the brackets is from Briggs (1971; 1972) and

$\bar{u}\{h\}$ = the mean wind speed (m/sec) at the stack height h

γ_1 = the adiabatic entrainment coefficient ~ 0.6 (Briggs, 1972)

F = the buoyancy flux (m^4/sec^3)

$$= \frac{gV}{\pi} \left(1 - \frac{T_a}{T_s} \right)$$

V = the volumetric emission rate of the stack (m^3/sec)

= $\pi r^2 w$

r = inner radius of stack (m)

w = stack exit velocity (m/sec)

g = the acceleration due to gravity (9.8 m/sec^2)

T_a = the ambient air temperature (^oK)

T_s = the stack exit temperature (^oK)

The factor f, which limits the plume rise as the mean wind speed at stack height approaches or exceeds the stack exit velocity, is the Cramer et al. (1975) stack-tip downwash correction and is defined by

$$f = \left\{ \begin{array}{cl} 1 & ; \quad \bar{u}\{h\} \leq w/1.5 \\ \left(\frac{3w - 3\bar{u}\{h\}}{w} \right) & ; \quad w/1.5 < \bar{u}\{h\} < w \\ 0 & ; \quad \bar{u}\{h\} \geq w \end{array} \right\} \tag{2-5}$$

The correction factor f given by Equation (2-5) is intended to account for the effects on buoyant plume rise of downwash in the lee of the stack during periods when the wind speed at stack height is greater than or equal to 0.67 times the stack exit velocity. In our opinion, the effects on plume rise of downwash in the lee of the stack are usually more important than the effects of building wakes if the stack height to building height ratio is greater than about 1.2 to 1.5. The rationale for the semi-empirical correction factor f is outlined in Appendix G. As explained in the appendix, it has been our experience that the correction factor f given by Equation (2-5) should not be used for stacks with Froude numbers less than 1.0 and that Equation (2-5) may not apply for stacks with Froude numbers between 1.0 and 3.0. We have no basis at present for predicting in advance whether a stack-tip downwash correction is needed for stacks with Froude numbers in the range 1.0 to 3.0. The Froude number is given by Briggs (1969, p. 6) as

$$Fr = \frac{w^2}{g\left(\frac{T_s - T_a}{T_a}\right) D} \tag{2-6}$$

where D is the stack inner diameter.

Inspection of Equation (2-4) shows that SHORTZ and LONGZ assume that final plume rise under adiabatic or unstable conditions is attained at a downwind distance of ten stack heights (10h). Although this distance to stabilization was originally proposed by Briggs (1969), Briggs (1971) defined the distance to stabilization as 3.5x*, where x* is a function of the buoyancy flux F. However, discussions between Briggs and the H. E. Cramer Company during 1974 revealed that either the 10h or the 3.5x* approach provided essentially the same correspondence between calculated and observed plume rises for the available stack data. Additionally, we have obtained the best correspondence between calculated and observed plume rises for tall stacks by assuming that the distance to stabilization is 10h (see Bowers and Cramer, 1976). In his more recent work, Briggs (1975) includes the friction velocity and the stack height in determinations of the distance to stabilization, but notes that 10h is a good approximation to this distance for most power plant stacks. (It is important to recognize that the 10h distance to stabilization used by SHORTZ and LONGZ may significantly underestimate buoyant plume rise for some non-stack sources such as gas turbines.)

The modified Briggs (1971; 1972) plume-rise equation used by the SHORTZ and LONGZ programs for a stable atmosphere (vertical potential temperature gradient greater than zero) is

$$\Delta h_S = \left\{ \begin{array}{ll} \left[\dfrac{6F}{\bar{u}\{h\}\,\gamma_2^{\,2}\, S} \right]^{1/3} & ; \pi\, \bar{u}\{h\}\, S^{-1/2} < 10h \\ \\ \left[\dfrac{3F}{\bar{u}\{h\}\gamma_2^{\,2}\, S} \left(1 - \cos\left(\dfrac{10S^{1/2}\, h}{\bar{u}\{h\}} \right) \right) \right]^{1/3} & ; \pi\, \bar{u}\{h\}\, S^{-1/2} \geq 10h \end{array} \right\} f \qquad (2\text{-}7)$$

where

γ_2 = the stable entrainment coefficient ~ 0.66 (Briggs, 1972)

$S = \dfrac{g}{T_a} \dfrac{\partial\theta}{\partial z}$ (sec^{-2})

$\dfrac{\partial\theta}{\partial z}$ = vertical potential temperature gradient ($^{\circ}$K/m)

It should be noted that Equation (2-7) does not permit the calculated stable rise Δh_S to exceed the adiabatic rise Δh_N as the atmosphere approaches a neutral stratification ($\partial\theta/\partial z$ approaches zero). A procedure of this type is also recommended by Briggs (1972).

2.3 THE SHORTZ DISPERSION MODEL EQUATIONS

2.3.1 Stack Emissions

The SHORTZ concentration model for stacks uses the steady-state Gaussian plume equation for a continuous elevated source. For each stack and each set of short-term meteorological inputs, the stack's coordinate system is placed at the ground surface at the base of the stack. The x axis is positive in the downwind direction, the y axis is crosswind (normal) to the x axis and the z axis extends vertically. The fixed receptor locations are converted to each stack's coordinate system for each short-term concentration calculation. The short-term concentrations calculated for the various stacks at each receptor are summed to obtain the total concentration produced at each receptor by the combined stack emssions.

The short-term ground-level concentration at downwind distance x and crosswind distance y is given by

$$\chi\{x,y\} = \frac{K\,Q}{\pi\,\bar{u}\{H\}\,\sigma_y\,\sigma_z}\ \{\text{Vertical Term}\}\ \{\text{Lateral Term}\}\ \{\text{Decay Term}\} \qquad (2\text{-}8)$$

where

Q = pollutant emission rate (mass per unit time)

K = scaling coefficient to convert calculated concentrations to desired units (default value of $1\text{x}10^6$ for Q in g/sec and concentration in $\mu g/m^3$)

$u\{H\}$ = mean wind speed (m/sec) at the plume stabilization height H

σ_y, σ_z = standard deviations (m) of the lateral and vertical concentration distributions at downwind distance x (σ_y and σ_z are also known as lateral and vertical dispersion coefficients)

The Vertical Term

The Vertical Term refers to the plume expansion in the vertical or z direction and includes a multiple reflection term that limits cloud growth to the surface mixing layer. For gaseous pollutants and small particulates, the Vertical Term is given by

$$\{\text{Vertical Term}\} = \left\{ \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] + \sum_{i=1}^{\infty}\left[\exp\left[-\frac{1}{2}\left(\frac{2i\ H_m + H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{2i\ H_m - H}{\sigma_z}\right)^2\right]\right]\right\} \qquad (2\text{-}9)$$

where H_m is the depth of the surface mixing layer. The exponential terms in the series in Equation (2-9) rapidly approach zero near the source. At the downwind distance where the exponential terms for i equal 3 exceed exp(-10), the plume has become approximately uniformly mixed within the surface mixing layer. In order to reduce computer computation time without loss of accuracy, Equation (2-9) is changed to the form

$$\{\text{Vertical Term}\} = \frac{\sqrt{2\pi}\ \sigma_z}{2H_m} \qquad (2\text{-}10)$$

beyond this point. Equation (2-10) changes the form of the vertical concentration distribution from Gaussian to rectangular. If H exceeds H_m, the Vertical Term is set equal to zero which results in a zero value for the ground-level concentration.

The Lateral Term

The Lateral Term refers to the crosswind expansion of the plume and is given by the expression

$$\{\text{Lateral Term}\} = \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \qquad (2\text{-}11)$$

where y is the crosswind distance from the plume centerline to the point at which concentration is calculated.

The Decay Term

The Decay Term, which accounts for the pollutant removal by physical or chemical processes, is of the form

$$\left\{\text{Decay Term}\right\} = \exp\left[-\psi\, x/\bar{u}\{H\}\right] \tag{2-12}$$

where

ψ = the washout coefficient $\Lambda(\sec^{-1})$ for precipitation scavenging

= $\frac{0.692}{T_{1/2}}$, where $T_{1/2}$ is the pollutant half life (sec) for physical or chemical removal

= 0 for no depletion (ψ is automatically set to zero by the computer program unless otherwise specified)

The Dilution (Wind-Speed) Term

In the model calculations, the observed mean wind speed $\bar{u}_R$ is adjusted from the measurement height z_R to the source height h for plume-rise calculations and to the plume stabilization height H for the concentration calculations by a wind-profile exponent law

$$\bar{u}\{z\} = \bar{u}\{z_R\}\left(\frac{z}{z_R}\right)^{p} \tag{2-13}$$

Model assumptions about the variation with height of the wind speed in complex terrain are outlined in Section 2.5.

Downwind and Crosswind Distances

Both the SHORTZ and LONGZ programs use either a polar or a Cartesian receptor grid as specified by the user. Additionally, either polar or Cartesian coordinates may be used to define source locations for either type of receptor grid. In the polar coordinate system, the radial coordinate r of the point (r, θ) is measured from the origin and the angular coordinate θ is measured clockwise from north. In the Cartesian coordinate system, the X-axis is positive to the east and the Y-axis is positive to the north. In the polar coordinate system, the X and Y coordinates of a receptor or a source at the point (r, θ) are given by

$$X = r \sin \theta \tag{2-14}$$

$$Y = r \cos \theta \tag{2-15}$$

The Cartesian coordinate system is used by the SHORTZ and LONGZ programs to calculate downwind and crosswind distances. Thus, receptor and/or source locations entered in polar coordinates are first converted to Cartesian coordinates using Equations (2-14) and (2-15). If the X and Y coordinates of the source are $X(S)$ and $Y(S)$ and the X and Y coordinates of the receptor are $X(R)$ and $Y(R)$, the downwind distance x to the receptor is given by

$$x = -\big(X(R) - X(S)\big) \sin DD - \big(Y(R) - Y(S)\big) \cos DD \tag{2-16}$$

where DD is the direction from which the wind is blowing. Similarly, the crosswind distance y to the receptor is given by

$$y = -\big(Y(R) - Y(S)\big) \sin DD + \big(X(R) - X(S)\big) \cos DD \tag{2-17}$$

Dispersion Coefficients

The dispersion coefficients used by both the SHORTZ and LONGZ programs are often identified as "Cramer dispersion coefficients" because they are the most recent versions (see Cramer, 1976) of the expressions originally proposed by Cramer (1957). The "Cramer" σ_y and σ_z equations include the effects of initial source dimensions and directly relate lateral and vertical plume spread to the lateral and vertical turbulent intensities.

According to the derivation in the report by Cramer, *et al.* (1972), the standard deviation of the lateral concentration distribution σ_y, which is used by SHORTZ only, is given by the expressions

$$\sigma_y\{x\} = \sigma'_A \, x_{ry} \left[\frac{x + x_y - x_{ry}(1-\alpha)}{\alpha \, x_{ry}} \right]^{\alpha} \tag{2-18}$$

$$x_y = \left\{ \begin{array}{ll} \dfrac{\sigma_{yR}}{\sigma'_A} - x_R & ; \quad \dfrac{\sigma_{yR}}{\sigma'_A} \leq x_{ry} \\ & \\ \alpha \, x_{ry} \left(\dfrac{\sigma_{yR}}{x_{ry} \, \sigma'_A} \right)^{1/\alpha} - x_R + x_{ry}\,(1-\alpha) & ; \quad \dfrac{\sigma_{yR}}{\sigma'_A} > x_{ry} \end{array} \right\} \tag{2-19}$$

where

σ'_A = the standard deviation of the wind-direction angle or lateral turbulent intensity in radians for the averaging time of the input meteorological data

x_y = the lateral virtual distance in meters (note that SHORTZ does not permit x_y to be less than zero)

x_{ry} = distance in meters over which rectilinear lateral plume expansion occurs downwind from an ideal point source

σ_{yR} = the standard deviation of the lateral concentration distribution at downwind distance x_R (m)

α = the lateral diffusion coefficient

On the basis of diffusion experiments conducted at Dugway Proving Ground, Utah and elsewhere, x_{ry} has a nominal value of about 50 meters (Cramer, et al., 1972). Similarly, the lateral diffusion coefficient α (in our terminology), which should not be confused with the lateral dispersion coefficient σ_y, has a nominal value of 0.9.

If x_y is set equal to zero (i.e., a point source is assumed), x_{ry} is set equal to 50 meters, α is set equal to 0.9 and the lateral turbulent intensities given for rural areas in Table 2-3 are entered in Equation (2-18), the resulting σ_y values are in very close agreement with the corresponding values obtained from the Pasquill-Gifford curves (Turner, 1969). We point out that Equation (2-18) does not explicitly contain the effects of vertical wind-direction shear. Irwin (1979) and others have proposed expressions for σ_y that are similar in form to Equation (2-18), but that yield much smaller σ_y values beyond a few kilometers if wind shear effects are not considered because σ_y becomes proportional to $x^{0.5}$ at and beyond 10 kilometers. (The Irwin σ_y equation explicitly provides for the inclusion of the effects of wind-direction shear.) For continuous sources, the data on lateral dispersion in the atmosphere reported by Draxler (1979) and others establish an approximate $x^{0.9}$ distance dependence for σ_y. For example, Bigg, et al. (1978) report measured σ_y values proportional to about $x^{0.9}$ as far as 560 kilometers downwind from an isolated smelter. The fact that σ_y is proportional to $x^{0.9}$ rather than $x^{0.5}$ may in part reflect the effects of wind shear. Consequently, we recommend that α be set equal to 0.9 in Equation (2-18) at all downwind distances.

The equation for the vertical dispersion coefficient σ_z used by the SHORTZ and LONGZ programs is very similar to equations proposed by Yamamoto and Yokoyama (1974) for stack emissions, by Irwin (1979) for convectively unstable conditions and by Hanna, et al. (1977) for elevated sources at short downwind distances. Following the derivation of Cramer, et al. (1972) and setting the vertical diffusion coefficient β equal to unity, the standard deviation of the vertical concentration distribution is given by the expressions

$$\sigma_z\{x\} = \sigma'_E \left(x + x_z\right) \tag{2-20}$$

$$x_z = \left\{ \begin{array}{lll} \dfrac{\sigma_{zR}}{\sigma'_E} - x_R & ; & \dfrac{\sigma_{zR}}{\sigma'_E} \geq x_R \\ & & \\ 0 & ; & \dfrac{\sigma_{zR}}{\sigma'_E} < x_R \end{array} \right\} \tag{2-21}$$

where

σ'_E = the standard deviation of the wind elevation angle or vertical turbulent intensity in radians

σ_{zR} = the standard deviation of the vertical concentration distribution at downwind distance x_R (m)

It is important to note that Equation (2-20) is not valid at long downwind distances unless Equation (2-9) is used to restrict the plume within the surface mixing layer.

Initial Plume Dimensions

Briggs (1972) notes that numerous observations of plumes near the stack show that the plume radius is approximately equal to half the plume rise. The lateral and vertical virtual distances given respectively by Equations (2-19) and (2-21) contain the lateral (σ_{yR}) and vertical (σ_{zR}) source dimensions at downwind distance x_R. Assuming that the lateral and vertical plume dimensions are the same during the period when entrainment is the dominant mechanism for plume growth and that the initial lateral and vertical concentration distributions are Gaussian, it follows that

$$\sigma_{yR} = \sigma_{zR} = \frac{0.5\ \Delta h}{2.15} \tag{2-22}$$

The distance x_R is the downwind distance to plume stabilization if the plume rise in Equation (2-22) is the final plume rise. According to Equations (2-2) and (2-7), the downwind distance to plume stabilization is given by

$$x_R = \left\{ \begin{array}{lll} 10h & ; & \frac{\partial\theta}{\partial z} \leq 0 \\ \pi\, \bar{u}\{h\} S^{-1/2} & ; & \frac{\partial\theta}{\partial z} > 0 \text{ and } \pi\, \bar{u}\{h\} S^{-1/2} < 10h \\ 10h & ; & \frac{\partial\theta}{\partial z} > 0 \text{ and } \pi\, \bar{u}\{h\} S^{-1/2} \geq 10h \end{array} \right\} \tag{2-23}$$

2.3.2 Building Source Emissions

A building source is defined as a building with emissions discharged at low exit velocity and with minimal thermal buoyancy from vents or short stacks located on or immediately adjacent to the building. The SHORTZ and LONGZ programs assume that such low-level emissions are rapidly distributed by the cavity circulation of the building wake and quickly assume the dimensions of the building. Thus, a building source may also be defined as a stack (vent) or group of stacks (vents) whose emissions are always or almost always subject to building wake effects. Any stack with a stack height to building height ratio less than about 1.5 is a potential building source and any stack with a stack height to building height ratio less than about 1.2 is a probable building source. However, emissions from a stack with a stack height to building height ratio less than about 1.2, but with a high exit velocity, generally do not behave as building source emissions except during periods when the wind speed at stack height equals or exceeds the stack exit velocity. It follows from the above discussion that in some cases it may be difficult to know whether to model a stack (stacks) as a stack (stacks) or as a building source. If the source is an existing source, visual observations of plume behavior and/or air quality monitoring may be used to gain insight into the appropriate modeling approach.

The building source model preserves the horizontal geometry of the source, assumes no buoyant plume rise and enhances the initial rate of dispersion. SHORTZ uses Equation (2-8) to calculate ground-level concentrations for building sources. The standard deviation of the lateral concentration distribution at the downwind edge of the source σ_{yo} is defined by the building crosswind dimension y_o divided by 4.3 (σ_{yo} corresponds to σ_{yR} in Equation (2-19) with x_R equal to one-half of the alongwind building length x_o). Similarly, the standard deviation of the vertical concentration distribution at the downwind edge of the source σ_{zo} is defined by the building height divided by 2.15 (σ_{zo} corresponds to σ_{zR} in Equation (2-21) with x_R equal to one-half of the alongwind building length x_o). In the original versions of SHORTZ and LONGZ used by Cramer, et al. (1975), the effective emission height H was set equal to zero. However, on the basis of the wind tunnel experiments described by Huber and Snyder (1976), the effective emission height H is currently set equal to the building height h. Although the original SHORTZ building source model was developed prior to the Huber and Snyder (1976) experiments, the modified building source model with H equal to h yields results that are in good agreement with their data.

It is important for the user to note that: (1) Concentrations calculated within about 20 to 30 building heights of a building source are subject to considerable uncertainty because of the uncertainties about near-field building wake effects in the atmosphere; (2) The length of a building source should not be more than about double the width; and (3) Line sources may be simulated with multiple building sources. Although Huber and Snyder (1976) provide techniques for calculating ground-level concentrations at downwind distances as short as three building heights, recent tests of these procedures using field data indicate that further research in the area of near-field building wake effects is still required (Bowers and Anderson, 1981). Section 2.1.2 explains why a long building should be subdivided into multiple building sources with lengths less than or equal to twice their widths in order to maintain computational accuracy. If possible, sufficient subsources should be used so that the length and width are equal for each subsource. A line source may be represented by multiple building sources with widths equal to the width of the line source, "building heights" equal to the effective emission height or heights of the line-source segments, and lengths less than or equal to twice the width of the line source. However, as discussed in Section 2.3.3, multiple area sources are generally used to simulate line sources.

2.3.3 Area Source Emissions

In urban areas there are often numerous low-level sources of pollutant emissions that individually have a negligible air quality impact, but that in combination may have a significant impact. For this type of emissions, the urban area is typically subdivided into a regularly-spaced grid of area sources, and emissions within each area source are assumed for modeling purposes to be uniformly distributed over the source. A second type of area source is a specific area of fugitive emissions such as a slag dump, an ore storage pile or a rail line for open ore cars. The SHORTZ and LONGZ area source models are designed for application to both types of area source emissions. The area source equation in both programs is based on the equation for a continuous and finite crosswind line source, integrated over the along-wind length of the source. Although a characteristic height scale h is used to account for enhanced initial dispersion, the SHORTZ and LONGZ area source models assume surface-based emissions.

The equation used by SHORTZ to calculate ground-level concentrations at downwind distance x from the edge of an area source is given by the expression

$$X\{x,y\} = \frac{KQ}{\sqrt{2\pi}\,\bar{u}\{h\}\,\sigma_z\{x\}\,y_o}\,\{\text{Vertical Term}\}\,\{\text{Lateral Term}\}\,\{\text{Decay Term}\} \tag{2-24}$$

where

Q = area source emission rate (mass per unit time)

y_o = crosswind source dimension (m)

h = the characteristic height of the area source (m)

The Decay Term is given by Equation (2-12) in Section 2.3.1 above. The remaining terms are given below.

Vertical Term

The Vertical Term for an area source for gases and small particulates is given by

$$\{\text{Vertical Term}\} = \begin{cases} 1+2\displaystyle\sum_{i=1}^{3} \exp\left[-\frac{1}{2}\left(\frac{2iH_m}{\sigma_z\{x\}}\right)^2\right] & ;\ \frac{1}{2}\left(\frac{6H_m}{\sigma_z}\right)^2 \geq 10 \\[2ex] \dfrac{\sqrt{2\pi}\,\sigma_z\{x\}}{2\,H_m} & ;\ \frac{1}{2}\left(\frac{6H_m}{\sigma_z}\right)^2 < 10 \end{cases} \tag{2-25}$$

Lateral Term

The Lateral Term is given by the expression

$$\{\text{Lateral Term}\} = \left\{ \text{erf}\left[\frac{y_o/2 + y}{\sqrt{2}\,\sigma_y\{x\}}\right] + \text{erf}\left[\frac{y_o/2 - y}{\sqrt{2}\,\sigma_y\{x\}}\right] \right\} \qquad (2\text{-}26)$$

where

y_o = crosswind dimension of the area source (m)

y = crosswind distance of the receptor from the centerline of the area source (m)

Dispersion Coefficients

The lateral dispersion coefficient σ_y for an area source is given by

$$\sigma_y\{x\} = \sigma_A'\left(x + x_o/2\right) \qquad (2\text{-}27)$$

where x_o is the alongwind dimension of the area source in meters. Similarly, the vertical dispersion coefficient σ_z for an area source is given by

$$\sigma_z\{x\} = \begin{cases} \dfrac{\sigma_E'\,x_o}{\ln\left[\dfrac{\sigma_E'\,(x+x_o) + h}{\sigma_E'(x) + h}\right]} & ; \quad x < 3\,x_o \\[2ex] \sigma_E'\left(x + x_o/2\right) + h & ; \quad x \geq 3\,x_o \end{cases} \qquad (2\text{-}28)$$

Concentrations Within an Area Source

The concentration within an area source due to the source's own emissions is given by

$$\chi\{x'\} = \frac{2KQ}{\sqrt{2\pi}\ \bar{u}\{h\}\ x_o\ y_o\ \sigma'_E} \left\{ \ln \left[\frac{\sigma'_E\ (x' + 1) + h}{\sigma'_E + h} \right] \right\} \{\text{Vertical Term}\} \qquad (2\text{-}29)$$

where

x' = distance downwind from the upwind edge of the area source (m)

The Vertical Term in Equation (2-29) is defined by Equation (2-25). Note that the vertical dispersion coefficient σ_z is contained in Equation (2-29) (see Equation (2-28)).

Guidance on the Application of the Area Source Model

For the reasons given in Section 2.1.2 above, the length of an individual area source should be less than or equal to twice the width of the source and preferably should be approximately equal to the width. Thus, multiple area sources are required to simulate the effects of emissions from narrow area sources such as a rail line carrying uncovered ore cars. Figure 2-2 illustrates the representation of a curved and narrow area source (i.e., a curved line source) by multiple area sources. The length and width of each individual area source are set equal to the width of the line source, and the characteristic height h of the area source is set equal to the physical height of the source. For example, the characteristic height for an ore pile is the height of the ore pile, the characteristic height for a rail line carrying uncovered ore cars is the height of the ore cars, and the characteristic height of an urban area source simulating the effects of emissions from home heating is the typical height of the homes in the area.

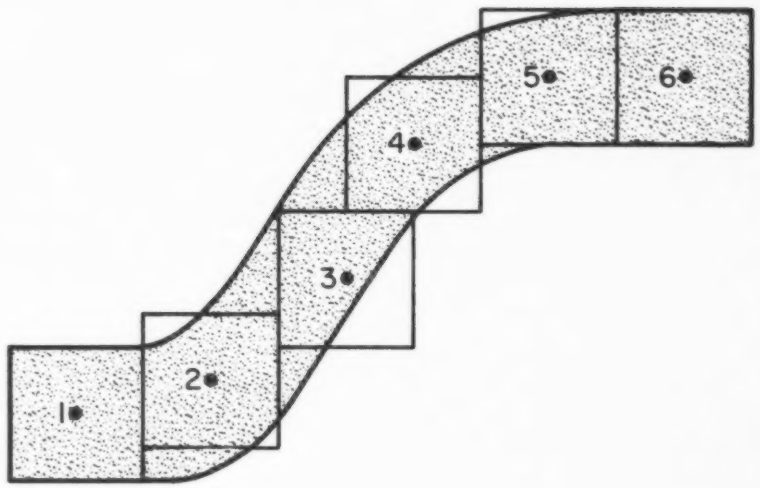


FIGURE 2-2. Representation of a curved line source by multiple area sources.

2.3.4 Modification of the Stack, Building and Area Source Models to Account for Gravitational Settling

The dispersion of particulates with appreciable gravitational settling velocities (diameters greater than about 20 micrometers) differs from that of gaseous pollutants and small particulates in that the larger particulates are brought to the ground surface by the combined processes of atmospheric turbulence and gravitational settling. Additionally, gaseous pollutants and small particulates tend to be reflected from the surface, while larger particulates that come in contact with the surface may be completely or partially retained at the surface. In the SHORTZ and LONGZ programs, gravitational settling is assumed to result in a tilted plume with the plume axis inclined to the horizontal at an angle given by arctan $(V_s/\bar{u})$, where V_s is the gravitational settling velocity. The Vertical Term used by SHORTZ and LONGZ for particulates with appreciable gravitational settling velocities corresponds to the Vertical Term of the Industrial Source Complex (ISC) Dispersion Model (Bowers, et al., 1979) with the surface reflection coefficient set equal to zero. That is, all of the material that comes in contact with the surface is assumed to be retained at the surface, an assumption that is likely to be invalid if the lower bound on the particulate-size distribution is less than about 20 micrometers. Consequently, the user may wish to make two separate runs in order to consider the combined effects of gravitational settling and dry deposition. In the first run, the fraction of particulates with diameters less than 20 micrometers is modeled as a gaseous pollutant. In the second run, the particulates with diameters above 20 micrometers are divided by the user into N gravitational settling-velocity categories (the maximum value of N is 20) and concentrations are calculated using the gravitational settling option. The results of the two runs are then combined, either manually or by using the master tape inventory (see Section 1.3.1), to obtain the total ground-level concentrations.

The ground-level concentration of particulates with appreciable gravitational settling velocities is given by Equation (2-8) or Equation (2-24) with the Vertical Term defined as (Cramer, et al., 1972)

$$\{\text{Vertical Term}\} = \sum_{n=1}^{N} \frac{\phi_n}{2} \left\{ \exp\left[-\frac{1}{2}\left(\frac{H - V_{sn}\, x/\bar{u}\{H\}}{\sigma_z} \right)^2 \right] + \exp\left[-\frac{1}{2}\left(\frac{2H_m - H + V_{sn}\, x/\bar{u}\{H\}}{\sigma_z} \right)^2 \right] \right\} \tag{2-30}$$

where

ϕ_n = the mass fraction of particulates with settling velocity V_{sn}, where V_{sn} is in meters per second

H = the effective stack height for stack sources, the building height for building sources and zero for area sources (m)

Use of Equation (2-30) requires a knowledge of both the particulate-size distribution and the density of the particulates emitted by each source. The total particulate emissions for each source are subdivided by the user into a maximum of 20 categories and the gravitational settling velocity is calculated for the mass-mean diameter of each category. The mass-mean diameter is given by

$$\bar{d} = \left[\frac{d_2^3 + d_1^2 d_2 + d_1 d_2^2 + d_1^3}{4} \right]^{1/3} \tag{2-31}$$

where d_1 and d_2 are the lower and upper bounds of the particulate-size category. (McDonald (1960) gives simple techniques for calculating the gravitational settling velocity.) The user is cautioned that Equation (2-30) assumes that the terrain is flat or gently rolling. Consequently, *the gravitational settling option cannot be used for sources located in complex terrain without violating mass continuity.*

2.4 THE LONGZ DISPERSION MODEL EQUATIONS

The LONGZ computer program implements a sector-averaged long-term concentration model that is similar in form to the Air Quality Display Model (EPA, 1969) or the Climatological Dispersion Model (Calder, 1971). In the long-term model, which makes the same basic assumptions as the short-term model contained in the SHORTZ program, the area surrounding a continuous source of pollutants is divided into sectors of equal angular width corresponding to the sectors of the seasonal and annual frequency distributions of wind direction. Seasonal or annual emissions from the source are partitioned among the sectors according to the frequencies of wind blowing toward the sectors. The ground-level concentration fields calculated for each source are translated to a common receptor system (either polar or Cartesian as specified by the user) and summed to obtain the total due to all sources. The model equations used by the LONGZ program are discussed in this section. However, the reader is referred to the corresponding subsections in Section 2.3 as well as to Sections 2.1.1.2 and 2.1.2 for technical guidance on the application of the LONGZ program.

2.4.1 Stack Emissions

For a single stack, the mean seasonal concentration of a gaseous pollutant or of small particulates at the point (r,θ) with respect to the stack is given by

$$\chi_{\ell}\{r,\theta\} = \frac{2K}{\sqrt{2\pi}\ r\ \Delta\theta'} \sum_{i,j,k} \left[\frac{Q_{i,k,\ell}\ f_{i,j,k,\ell}}{\bar{u}_i \left\{H_{i,k,\ell}\right\} \sigma_{z;i,k,\ell}}\ S\{\theta\}\ V_{i,k,\ell} \right. \tag{2-32}$$

$$\left. \exp\left[-\psi\ r/\bar{u}_i \left\{H_{i,k,\ell}\right\}\right]\right]$$

$$V_{i,k,\ell} = \exp\left[-\frac{1}{2}\left(\frac{H_{i,k,\ell}}{\sigma_{z;i,k,\ell}}\right)^2\right] + \sum_{n=1}^{\infty}\left\{\exp\left[-\frac{1}{2}\left(\frac{2nH_{m;i,k,\ell} - H_{i,k,\ell}}{\sigma_{z;i,k,\ell}}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{2nH_{m;i,k,\ell} + H_{i,k,\ell}}{\sigma_{z;i,k,\ell}}\right)^2\right]\right\} \tag{2-33}$$

where

$Q_{i,k,\ell}$ = pollutant emission rate, which may be held constant or varied according to the i^{th} wind-speed category k^{th} stability or time-of-day category and ℓth season (mass per unit time)

$f_{i,j,k,\ell}$ = frequency of occurrence of the i^{th} wind-speed category, j^{th} wind-direction category and k^{th} stability or time-of-day category for the ℓ^{th} season

$\Delta\theta'$ = the sector width in radians

$S\{\theta\}$ = a smoothing function

$$S\{\theta\} = \begin{cases} \dfrac{\Delta\theta' - \left|\theta'_j - \theta'\right|}{\Delta\theta'} & ; \quad \left|\theta'_j - \theta'\right| \leq \Delta\theta' \\ 0 & ; \quad \left|\theta'_j - \theta'\right| > \Delta\theta' \end{cases} \tag{2-34}$$

θ'_j = the angle measured in radians from north to the centerline of the j^{th} wind-direction sector

θ' = the angle measured in radians from north to the point (r,θ)

The definitions of the remaining parameters are the same as those given in Section 2.3 for the SHORTZ program except that the i subscript refers to the wind-speed category, the j subscript refers to the wind-direction category, the k subscript refers to the stability or time-of-day category and the ℓ subscript refers to the season. As with the SHORTZ program, the Vertical Term given by Equation (2-33) is changed to the form

$$V_{i,k,\ell} = \frac{\sqrt{2\pi}\,\sigma_{z;i,k,\ell}}{2H_{m;i,k,\ell}} \qquad (2\text{-}35)$$

when the exponential terms in Equation (2-33) exceed exp (-10) for n equal to 3.

As shown by Equation (2-32), the user may assign a different pollutant emission rate to each combination of season, wind-speed and stability or time-of-day categories. This option is primarily designed for application to sources that use a Supplementary Control System (SCS) to vary stack emissions according to meteorological conditions (for example, see Cramer, et al., 1976). This option is also available for building and area sources and may be used to account for wind-blown particulate emissions that vary with wind speed and stability.

As shown by Equation (2-34), the rectangular concentration distribution within a given angular sector is modified by the function S which smoothes discontinuities in the concentration at the boundaries of adjacent sectors. The centerline concentration in each sector is unaffected by contributions from adjacent sectors. At points off the sector centerline, the concentration is a weighted function of the concentration at the centerline of the sector in which the calculation is being made and the concentration at the centerline of the nearest adjoining sector.

The mean annual concentration at the point (r,θ) is calculated from the seasonal concentrations using the expression

$$\chi_a\{r,\theta\} = \frac{1}{4} \sum_{\ell=1}^{4} \chi_\ell \{r,\theta\} \tag{2-36}$$

2.4.2 Building Source Emissions

The LONGZ building source model makes the same assumptions about the effects of building wakes on the dispersion of low-level emissions from building vents or stacks as the SHORTZ building source model. Equation (2-32) is used by LONGZ to calculate ground-level concentrations for building sources with the initial vertical dimension σ_{zo} given by the building height divided by 2.15 and the initial lateral dimension 4.3 σ_{yo} given by the diameter of a circle with the same horizontal area as the building. A virtual point source is used to account for the initial lateral dimension of the source in a manner identical to that described below for area sources.

2.4.3 Area Source Emissions

The mean seasonal concentration of a gaseous pollutant or of small particulates at downwind distance r and azimuth bearing θ with respect to the center of an area source is given by the expression

$$\chi_\ell\{r,\theta\} = \frac{2K}{\sqrt{2\pi}\, R\, \Delta\theta'} \left\{ \sum_{i,j,k} \left[\frac{Q_{i,k,\ell}\, f_{i,j,k,\ell}}{\bar{u}_i\{h\}\, \sigma_{z;i,k}}\, S\{\theta\}\ \ V_{i,k,\ell} \right] \exp\left[-\psi\left(r' - r_o\right)/\bar{u}_i\{h\} \right] \right\} \tag{2-37}$$

where

R = radial distance from the virtual point source to the receptor (m)

$$= \left(\left(r' + x_y \right)^2 + y^2 \right)^{1/2} \tag{2-38}$$

r' = distance from source center to receptor, measured along the sector centerline (m)

r_o = effective source radius (m)

y = lateral distance from the sector centerline to the receptor (m)

x_y = lateral virtual distance upwind from the source center, measured along the sector centerline (m)

$$= r_o \cot \frac{\Delta\theta'}{2} \tag{2-39}$$

$$\sigma_{z;i,k} = \begin{cases} \dfrac{2\sigma'_{E;i,k}\, r_o}{\ln \left[\dfrac{\sigma'_{E;i,k}\,(r'+r_o) + h}{\sigma'_{E;i,k}\,(r'-r_o) + h} \right]} & ; \quad r_o < r' < 6r_o \\[2ex] \sigma'_{E;i,k}\, r' + h & ; \quad r' \geq 6r_o \end{cases} \tag{2-40}$$

$$V_{i,k,\ell} = \begin{cases} 1+2 \displaystyle\sum_{n=1}^{3} \exp\left[-\frac{1}{2} \left(\frac{2nH_{m;i,k,\ell}}{\sigma_{z;i,k}} \right)^2 \right] & ; \quad \dfrac{1}{2} \left(\dfrac{6H_{m;i,k,\ell}}{\sigma_{z;i,k}} \right)^2 \geq 10 \\[3ex] \dfrac{\sqrt{2\pi}\, \sigma_{z;i,k}}{2H_{m;i,k,\ell}} & ; \quad \dfrac{1}{2} \left(\dfrac{6H_{m;i,k,\ell}}{\sigma_{z;i,k}} \right)^2 < 10 \end{cases} \tag{2-41}$$

and the remaining parameters are identical to those previously defined.

The seasonal average concentration within an area source attributable to the source's own emissions is given by the expression

$$\chi_\ell\{r'',\theta\} = \frac{2K}{\sqrt{2\pi}\; x_o y_o} \sum_{i,j,k} \left[\frac{Q_{i,k,\ell}\; f_{i,j,k,\ell}}{\bar{u}_i\{h\}\; \sigma'_{E;i,k}} \ln\left[\frac{\sigma'_{E;i,k}\;(r''+1) + h}{\sigma'_{E;i,k} + h} \right] V_{i,k,\ell} \right] \tag{2-42}$$

where

r'' = the downwind distance, measured along the sector centerline, from the upwind edge of the area source (m)

2.4.4 Modification of the Stack, Building and Area Source Models to Account for Gravitational Settling

The seasonal average ground-level concentration of particulates with appreciable gravitational settling velocities is given by Equation (2-32) or Equation (2-37) with the Vertical Term defined as

$$\begin{aligned} V_{i,k,\ell} = \sum_{n=1}^{N} \frac{\phi_n}{2} \Bigg[&\exp\left[-\frac{1}{2} \left(\frac{H_{i,k,\ell} - V_{sn}\; r/\bar{u}_i\; \{H_{i,k,\ell}\}}{\sigma_{z;i,k,\ell}} \right)^2 \right] \\ &+ \exp\left[-\frac{1}{2} \left(\frac{2H_{m;i,k,\ell} - H_{i,k,\ell} + V_{sn}\; r/\bar{u}_i\{H_{i,k,\ell}\}}{\sigma_{z;i,k,\ell}} \right)^2 \right] \Bigg] \end{aligned} \tag{2-43}$$

where ϕ_n is the mass fraction of particles with settling velocity V_{sn} and H is the effective stack height for stack sources, the building height for building sources and zero for area sources. As explained in Section 2.3.4, this option cannot be used for sources located in complex terrain without violating mass continuity.

2.5 APPLICATION OF SHORTZ AND LONGZ IN COMPLEX TERRAIN

The two general approaches for calculating ground-level concentrations in complex terrain are to modify a Gaussian plume model for flat terrain or to use a numerical model that considers variations in terrain height over the calculation grid. At present, either approach provides at best a very simple approximation of complex plume-terrain interactions. The SHORTZ and LONGZ computer programs modify the flat-terrain Gaussian plume models described in Sections 2.3 and 2.4 following the suggestions of Cramer, *et al*. (1975). The development and testing of the Cramer, *et al*. (1975) complex terrain modeling techniques are discussed in Appendix H. These techniques differ from previous modified Gaussian approaches in the treatment of the mixing depth in complex terrain and in the assumptions about terrain intersection for plumes contained within the surface mixing layer.

When applied in complex terrain, the SHORTZ and LONGZ programs modify the flat-terrain models described in Sections 2.3 and 2.4 by defining effective plume heights and mixing depths. The following assumptions are made in the model calculations for complex terrain:

- The actual top of the surface mixing layer extends over the calculation grid at a constant height above mean sea level; the *actual* top of the surface mixing layer should not be confused with the *effective* top of the surface mixing layer, which is a mathematical device used to preclude violations of the Second Law of Thermodynamics when plumes pass over elevated terrain

- The axis of a plume contained within the surface mixing layer remains at the plume stabilization height above mean sea level, and the plume may impact elevated terrain within the surface mixing layer under stable, neutral or unstable conditions

- Plumes that stabilize above the top of the surface mixing layer do not contribute to significant ground-level concentrations at any receptor (this assumption also applies to flat terrain), including receptors that are above the top of the surface mixing layer

In order to determine whether the stabilized plume is contained within the surface mixing layer, it is necessary to calculate the mixing depth $H_m^*\{z_s\}$ at the source from the relationship

$$H_m^*\{z_s\} = H_m + z_a - z_s \tag{2-44}$$

where

H_m = the depth of the surface mixing layer measured at a point with elevation z_a above mean sea level (m)

z_s = the height above mean sea level of the source (m)

Equation (2-44) is represented schematically in Figure 2-3, which assumes that z_a is the elevation of an airport. As shown by the figure, the actual top of the surface mixing layer is assumed to remain at a constant elevation above mean sea level. If the height H of the stabilized plume above the base of the stack is less than or equal to $H_m^*\{z_s\}$, the plume is defined to be contained within the surface mixing layer.

The height H_o of the stabilized plume above mean sea level is given by the sum of the height H of the stabilized plume above the base of the stack and the elevation z_s of the base of the stack. At any elevation z above mean sea level, the effective height $H'\{z\}$ of the plume centerline above the terrain is then given by

$$H'\{z\} = \left\{\begin{array}{ll} H_o - z & ; \; H_o - z \geq 0 \\ \\ 0 & ; \; H_o - z < 0 \end{array}\right\} \tag{2-45}$$

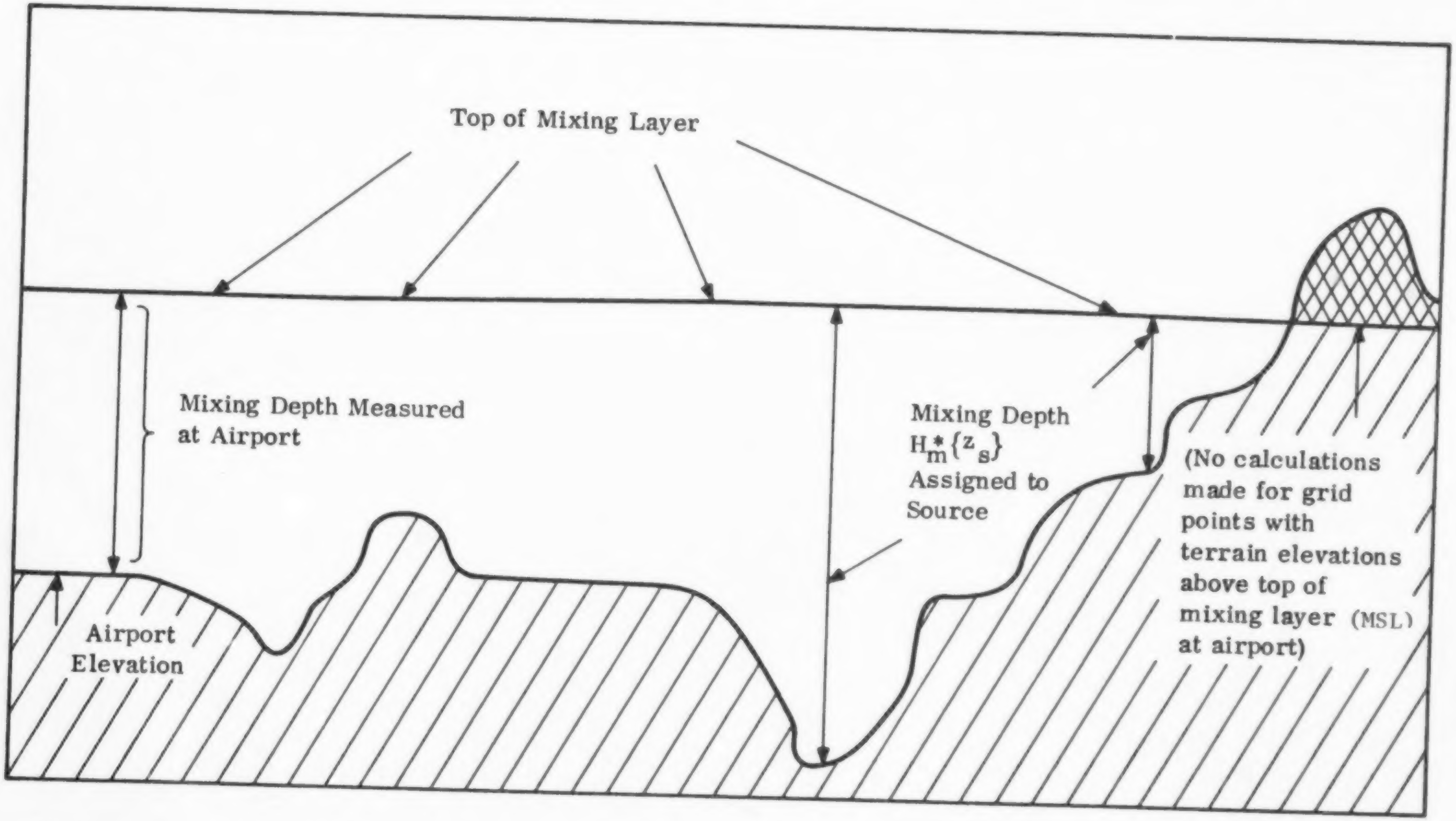

Top of Mixing Layer
Mixing Depth Measured at Airport
Airport Elevation
Mixing Depth $H_m^*\{z_s\}$ Assigned to Source
(No calculations made for grid points with terrain elevations above top of mixing layer (MSL) at airport)

FIGURE 2-3. Mixing depth $H_m^*\{z_s\}$ used to determine whether the stabilized plume is contained within the surface mixing layer.

The effective mixing depth $H'_m\{z\}$ above a point at elevation z above mean sea level is defined by

$$H'_m\{z\} = \left\{ \begin{array}{ll} H_m & ; \quad z \geq z_a \\ \\ H_m + z_a - z & ; \quad z < z_a \end{array} \right\} \qquad (2\text{-}46)$$

Figure 2-4 illustrates the assumptions implicit in Equation (2-46). For receptors at elevations below the airport elevation, the effective mixing depth $H'_m\{z\}$ is allowed to increase in a manner consistent with Figure 2-3. However, in order to prevent a physically unrealistic compression of plumes as they pass over elevated terrain, the effective mixing depth is not permitted to be less than the mixing depth measured at the airport. It should be noted that the concentration is set equal to zero for grid points above the actual top of the mixing layer (see Figure 2-3).

The SHORTZ or LONGZ user may assume that the wind speed is a function of the height above the ground surface (see Equation (2-13)) or a function of the height above mean sea level (MSL). However, in accord with the suggestions of Cramer, et al. (1975), we recommend that the wind speed be treated as a function of height above mean sea level. That is, the mean wind speed at any given height above mean sea level is assumed to be constant following the recommended modeling approach. Thus, the wind speed $\bar{u}_R$ measured at height z_R above the surface at a point with elevation z_a above mean sea level is adjusted to the stack height for the plume-rise calculations by the relationship

$$\bar{u}\{h\} = \left\{ \begin{array}{ll} \bar{u}_R \left(\dfrac{h_o - z_a}{z_R} \right)^p & ; \quad h_o \geq z_a + z_R \\ \\ \bar{u}_R & ; \quad h_o < z_a + z_R \end{array} \right\} \qquad (2\text{-}47)$$

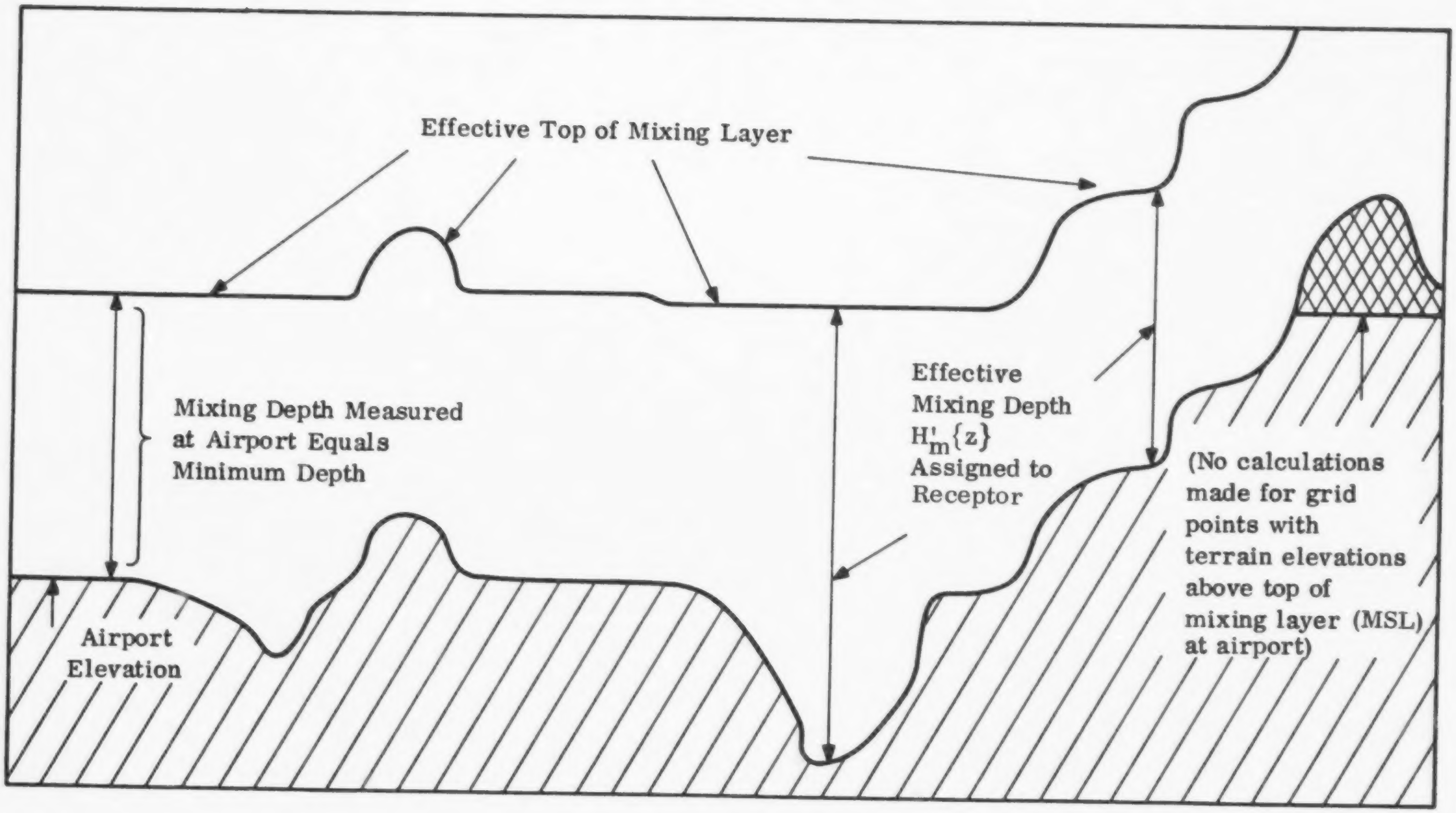

Effective Top of Mixing Layer
Mixing Depth Measured at Airport Equals Minimum Depth
Effective Mixing Depth $H'_m\{z\}$ Assigned to Receptor
(No calculations made for grid points with terrain elevations above top of mixing layer (MSL) at airport)
Airport Elevation

FIGURE 2-4. Effective mixing depth $H'_m\{z\}$ assigned to receptors for the concentration calculations.

where h_o is the height above mean sea level of the top of the stack. Similarly, the wind speed $\bar{u}\{H\}$ used in the concentration calculations is given by

$$\bar{u}\{H\} = \begin{cases} \bar{u}_R \left(\dfrac{H_o - z_a}{z_R} \right)^p & ; \ H_o \geq z_a + z_R \\ \\ \bar{u}_R & ; \ H_o < z_a + z_R \end{cases} \qquad (2\text{-}48)$$

where H_o is the plume stabilization height above mean sea level.

In the discussion of the complex terrain modeling techniques given above, an airport is assumed to be the location at which the wind and mixing depth observations are made. However, the SHORTZ or LONGZ user is not restricted to the use of airport data. Tower wind data may also be used with the elevation above mean sea level of the base of the tower substituted for the airport elevation z_a. If mixing depths are not measured at the location of the tower, a problem may arise because the programs contain provision for only one airport elevation z_a. Consequently, it may be necessary for the user to adjust mixing depths from a nearby location so that they are mixing depths above the tower elevation prior to input to the two programs. For example, if mixing depths are measured 50 meters above the elevation of the tower base, 50 meters should be added to all mixing depths used in the model calculations with the possible exception of mixing depths under stable conditions with a surface-based inversion when there is no objective indicator of the top of the surface mixing layer (see Section 2.1.1).

As discussed in Appendix H, the complex terrain modeling techniques contained in the SHORTZ and LONGZ programs have been tested by means of comparisons of calculated and observed concentrations for SO_2 sources located in complex terrain. The following recommendations on the application of SHORTZ and LONGZ to sources located in complex terrain are principally based on the experience gained during these studies. First, we believe that the use of onsite meteorological data is especially important in complex terrain. If onsite data are used with SHORTZ, it has been our experience that the highest calculated 24-hour average concentrations occur on nearby elevated terrain during periods of persistent moderate-to-strong winds in combination with neutral stability. All of our successful applications of the SHORTZ and LONGZ programs have involved the use of meteorological inputs developed following the general guidance given in Section 2.1.1. Consequently, we have no basis for assessing the accuracy of concentrations calculated using different techniques for assigning meteorological inputs. Additionally, because all of our comparisons of calculated and observed concentrations have been made at downwind distances beyond the downwind distance to plume stabilization, we have no basis for assessing the accuracy of concentrations calculated within about ten stack heights. Finally, we point out that the depth of the surface mixing layer critically affects the results of SHORTZ and LONGZ concentration calculations. The definition of mixing depth implicit in the terrain-adjustment procedures is based on the vertical profile of the vertical turbulent intensity (see Section 2.1.1.1) rather than thermal stratification alone. Following our modeling approach, a zero mixing depth is not possible. Thus, the appropriate mixing depths should be carefully assigned by an experienced meteorologist. The use of a mixing depth interpolation scheme such as that used by the preprocessor program for the Single Source (CRSTER) Model (EPA, 1977) could lead to highly erroneous results in SHORTZ calculations. If the limitations of the available data require the use of a mixing depth interpolation scheme, the scheme illustrated in Figure 2-1 and implemented by the SHORTZ meteorological preprocessor program contained in Appendix I should be used.

There is one special, principally hypothetical, situation in which our terrain-adjustment procedures result in calculated concentrations that may be as much as a factor of two higher than the concentrations that can actually occur. This situation arises when the central portion of the plume is at some elevation between the plume stabilization height and the ground surface and the axis of the plume impacts a vertical terrain wall extending above the height of the plume axis. Because of the assumption of complete reflection at the plume-terrain interface, the calculated concentration at the point where the plume axis impacts the wall is as much as a factor of two higher than the concentration on the plume axis immediately upwind of the wall, an obvious violation of the Second Law of Thermodynamics. Also, if the wall effectively precludes the downwind travel of the plume, the basic model assumptions relative to downwind plume transport are invalid. However, if the wall does not effectively impede the downwind transport of the plume, the plume becomes terrain-following beyond the initial point of impaction and the concentrations calculated by the model should be approximately correct. In all of the actual cases we have investigated to date of plume impaction on steeply-rising terrain, the maximum terrain slopes have been only about 20 degrees and the downwind transport of the plume has not been impeded. We therefore believe that the calculated concentrations are accurate.

In summary, there are three major points that should be kept in mind by the user with respect to the terrain-adjustment procedures in the SHORTZ and LONGZ programs as stated by Cramer, Geary and Bowers (1975) in the report on the Allegheny County SO_2 study:

(1) These terrain-adjustment procedures are simplified approximations of complex plume-terrain interactions that are currently not well understood.

(2) Terrain impaction is permitted to occur only when the plume is contained in the surface mixing layer. While this condition may occur with all stability categories, it is most likely to be associated with unstable or near-neutral stratifications and does not occur when the plume stabilization height is in a stable layer above the top of the surface mixing layer.

(3) These procedures may result in a calculated concentration as much as a factor of two higher than the actual concentration at the point where the central portion of the plume intersects a vertical terrain wall or very steeply-rising terrain before the plume has mixed to the ground surface.

2.6 EXAMPLE PROBLEM

2.6.1 Example SHORTZ Problem

The example SHORTZ problem is based on the 4 January 1973 air pollution episode at the Logans Ferry SO_2 monitor in Allegheny County. This case, which is also discussed in detail by Cramer, et al. (1975), was one of the first successful applications of the SHORTZ program. The source, meteorological and other SHORTZ inputs for the 4 January 1973 air pollution episode are given below, while Appendix C discusses the application of SHORTZ to this 24-hour period.

Figure 2-5 is a topographic map of the Springdale-Logans Ferry area. The filled circle in the figure shows the location of the Logans Ferry SO_2 monitor and the + symbols show the locations of the Cheswick and West Penn Power Plants. The West Penn Power Plant is about 900 meters west-southwest of the monitor, while the Cheswick Power Plant is about 3,100 meters west-southwest of the monitor. The two power plants are the only major SO_2 sources upwind of the monitor during periods of west-southwest winds. On 4 January 1973, strong west-southwest winds developed at about 0500 EST and persisted throughout the day. The 24-hour average SO_2 concentration observed at the monitor on 4 January 1973 was 891 micrograms per cubic meter. The corresponding 24-hour average SO_2 concentration calculated by Cramer, et al. (1975), using the modeling procedures outlined below, was 979 micrograms per cubic meter. The contributions to this total of the West Penn and Cheswick plants were 946 and 33 micrograms per cubic meter, respectively.

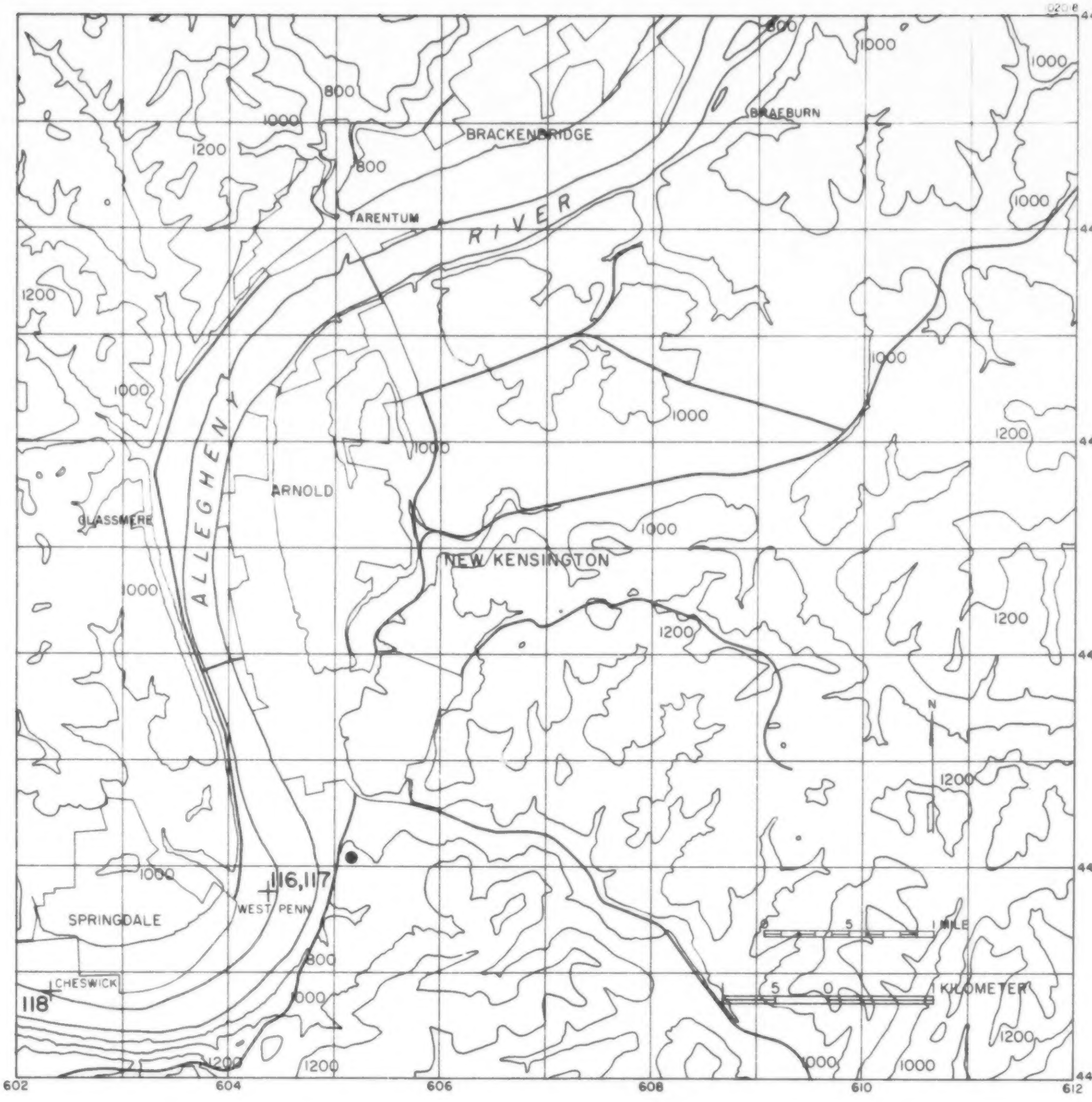

4497
1000
800
800
1000
BRACKENRIDGE
BRAEBURN
1200
800
1000
TARENTUM
RIVER
4495
1200
1000
1000
ALLEGHENY
1000
1000
1200
4493
ARNOLD
GLASSMERE
1000
NEW KENSINGTON
1000
1200
1200
4491
N
1200
1000
116,117
WEST PENN
4489
SPRINGDALE
800
5
1 MILE
CHESWICK
118
1000
5
0
1 KILOMETER
1200
1200
1200
1000
1000
4487
602
604
606
608
610
612

FIGURE 2-5. Topographic map of the Springdale-Logans Ferry area. Elevations are in feet above mean sea level, and the contour interval is 200 feet. The + symbols show the locations of the West Penn Power Plant (Sources 116 and 117) and the Cheswick Power Plant (Source 118). The filled circle shows the Logans Ferry SO_2 monitor.

The source and meteorological data for the 4 January 1973 air pollution episode at Logans Ferry are given in Tables 2-10 and 2-11, respectively. The source data in Table 2-10 were provided to the H. E. Cramer Company by the Allegheny County Bureau of Air Pollution Control. The meteorological inputs in Table 2-11 were developed from measurements made on 4 January 1973 at the Greater Pittsburgh Airport and Allegheny County Airport. The hourly wind directions and wind speeds are arithmetic means of the concurrent observations at the two airports. Rawinsonde data taken at the Greater Pittsburgh Airport at 1900 EST on 3 January, at 0700 and 1900 EST on 4 January, and at 0700 EST on 5 January were used to estimate mixing depths for the four observation times; mixing depths for intermediate hours were obtained by linear interpolation. The two Greater Pittsburgh Airport soundings on 4 January, as well as the 4 January 1200 EST sounding taken at the downtown Pittsburgh EMSU station, all showed a deep surface mixing layer with a near-adiabatic thermal stratification. Consequently, the vertical potential temperature gradient was set equal to zero for all hours of 4 January 1973. The ambient air temperatures listed in Table 2-11 are those observed at the Greater Pittsburgh Airport. Wind speeds from the four Greater Pittsburgh Airport soundings were averaged and a logarithmic least-squares regression curve was fitted to the data to obtain a value for the wind-profile exponent p of 0.17. Details of the regression technique are given in Section 2.1.1. Following the Turner (1964) criteria, the strong surface wind speeds and overcast clouds below 1000 meters require the Pasquill D stability category to be assigned to all hours of 4 January 1973. The hourly lateral and vertical turbulent intensities are therefore set equal to the urban values for the Pasquill D stability category of 0.1051 and 0.0735 radians, respectively (see Section 2.1.1.1). The non-meteorological inputs, including the coordinates and elevation of the Logans Ferry SO_2 monitor, are given in Table 2-12.

The purpose of this example SHORTZ problem is to use the inputs given in Tables 2-10 through 2-12 to calculate 24-hour average

TABLE 2-10

STACK AND EMISSIONS DATA FOR THE 4 JANUARY 1973 AIR POLLUTION EPISODE AT LOGANS FERRY

Source No.	Source Type	SO_2 Emission Rate (g/sec)	UTM X Coordinate (m)	UTM Y Coordinate (m)	Stack Height (m)	Stack Exit Temperature (°K)	Volumetric Emission Rate (m^3/sec)	Stack Radius (m)	Stack Elevation (m MSL)
116	0	318.15	604,380	4,488,740	67.1	472	160.98	2.60	229
117	0	318.15	604,380	4,488,740	62.5	444	162.14	1.85	229
118	0	1,260.00	602,330	4,487,800	229.0	411	881.46	3.20	229

TABLE 2-11

METEOROLOGICAL INPUT PARAMETERS FOR 4 JANUARY 1973

Hour (EST)	Wind Direction (deg)	Wind Speed (m/sec)	Mixing Depth (m)	Ambient Air Temperature (°K)	Potential Temperature Gradient (°K/m)	Pasquill Stability Category
01	170	5.4	953	283	0	D
02	190	6.7	1068	284	0	D
03	210	10.0	1184	285	0	D
04	220	9.8	1299	285	0	D
05	245	8.2	1415	283	0	D
06	255	9.3	1530	282	0	D
07	255	9.8	1645	280	0	D
08	250	10.3	1598	280	0	D
09	250	9.0	1551	280	0	D
10	250	8.5	1504	279	0	D
11	250	8.2	1457	279	0	D
12	250	7.2	1410	279	0	D
13	250	9.3	1363	279	0	D
14	250	7.7	1316	278	0	D
15	255	6.7	1269	278	0	D
16	260	6.2	1221	277	0	D
17	260	7.7	1174	276	0	D
18	265	6.7	1127	276	0	D
19	260	7.7	1080	275	0	D
20	250	6.7	1033	275	0	D
21	250	5.9	986	275	0	D
22	240	6.2	939	275	0	D
23	260	6.2	892	274	0	D
24	270	5.9	845	274	0	D

TABLE 2-12

NON-METEOROLOGICAL INPUTS FOR THE SHORTZ EXAMPLE PROBLEM

Input Parameter	Parameter Value
Lateral diffusion coefficient α	0.9*
Downwind distance for rectilinear lateral expansion x_{ry} (m)	50*
ROTATE (deg)	.683
Decay coefficient ψ ($\sec^{-1}$)	0*
Airport elevation (m MSL)	366.7
Wind system measurement height (m)	6.096*
Logans Ferry SO_2 Monitor:	
UTM X Coordinate (m)	605,167
UTY Y Coordinate (m)	4,489,107
Elevation (m MSL)	274

*Program default value.

ground-level SO_2 concentrations for the regularly-spaced UTM grid shown in Figure 2-5 and for the Logans Ferry SO_2 monitor. The source combinations of concern are:

- Sources 116 and 117 - the West Penn Power Plant
- Source 118 - the Cheswick Power Plant
- Sources 116 through 118 - all major SO_2 sources upwind from the Logans Ferry monitor with west-southwest winds

The detailed results of this example calculation and the program execution are discussed in Appendix C.

2.6.2 Example LONGZ Problem

The example LONGZ problem is to calculate the annual average ground-level particulate concentrations produced at and beyond the property boundary of the hypothetical aluminum reduction facility shown in Figure 2-6. The sources of particulate emissions are:

- The 60-meter Primary Scrubber System stack
- The 30-meter Carbon Baking Plant stack
- The three 25-meter stacks on the Metal Services Building
- The four Potroom roof monitors

The Potrooms, the Carbon Baking Plant and the Metal Services Building are all 15 meters high, and the three stacks serving the Metal Services Building are identical. The hypothetical aluminum plant is assumed to be located in an area of relatively flat terrain near the Greater Pittsburgh Airport. The following paragraphs discuss the development of the source, meteorological and other LONGZ inputs required to model the hypothetical aluminum plant. The execution of the LONGZ program for this example is discussed in Appendix D.

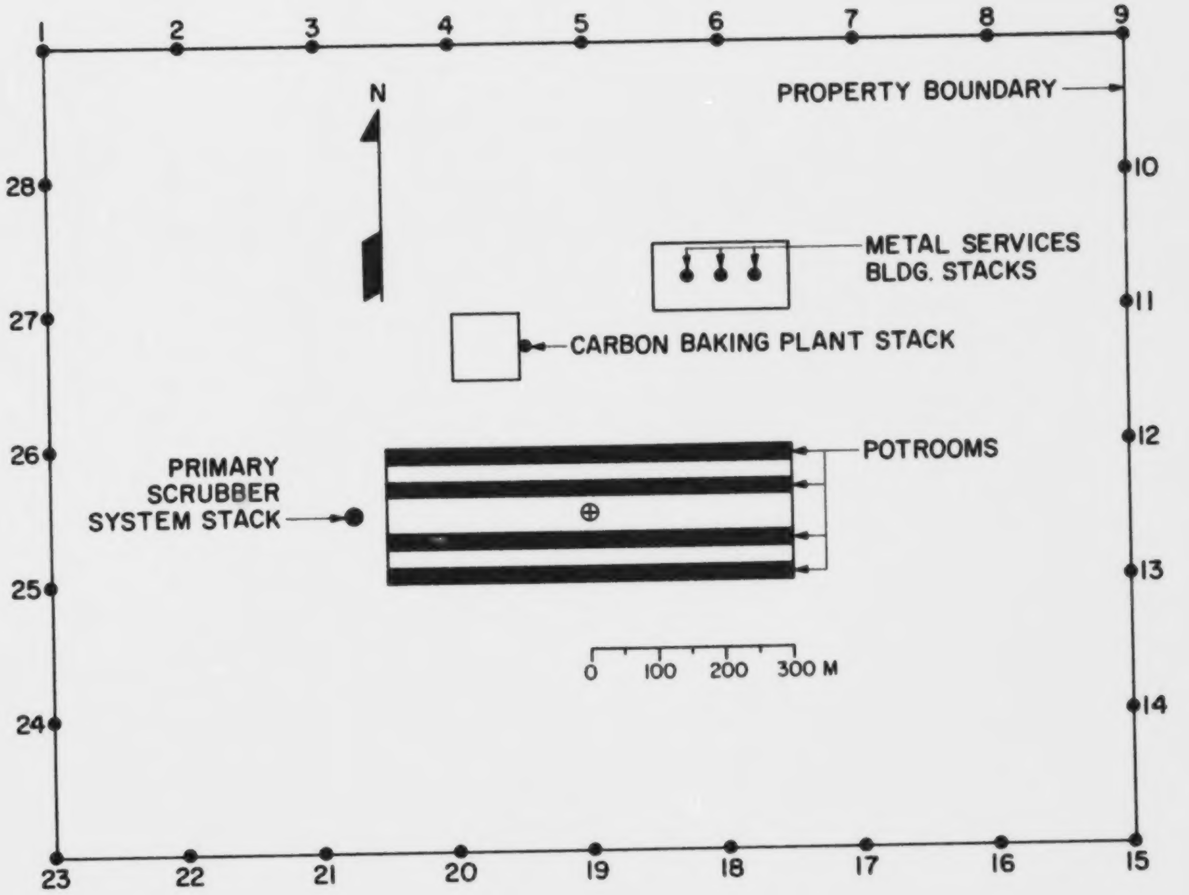

1
2
3
4
5
6
7
8
9
PROPERTY BOUNDARY
N
10
28
METAL SERVICES
BLDG. STACKS
11
27
CARBON BAKING PLANT STACK
26
PRIMARY
SCRUBBER
SYSTEM STACK
POTROOMS
12
⊕
25
13
0
100
200
300 M
24
14
23
22
21
20
19
18
17
16
15

FIGURE 2-6. Layout of a hypothetical aluminum reduction facility. The ⊕ symbol shows the origin of the receptor grid and the numbered filled circles show the locations of discrete receptors on the property boundary.

Table 2-13 lists the stack and emissions data for the hypothetical aluminum plant shown in Figure 2-6. The Potroom emissions are discharged from potline roof monitors at an exit velocity of about 1 meter per second with an exit temperature 10 degrees Celsius above the temperature of the ambient air. Consequently, the building source option is used to model the 200-meter by 600-meter Potroom complex. Because the length of an individual building source should not be more than twice its width, the Potroom complex is modeled as three 200-meter square building sources. Each of the five stacks has a Froude number well above 3.0, and the minimum stack height to building height ratio is 1.67 for the stacks on the Metal Services Building. Consequently, the correction factor f given by Equation (2-5) is assumed to apply to all of the stacks.

It is important to note that recent field and wind tunnel studies (see Schulman and Scire, 1980) suggest that the slightly buoyant emissions from the roof monitors at aluminum plants can attain appreciable buoyant plume rise because: (1) The large volume of discharged air results in a large buoyancy flux even though the temperature difference between the effluent and the ambient air is relatively small; and, (2) The adjacent buoyant plume elements that form the emissions from a roof monitor merge, resulting in a buoyant plume rise for the line source that is greater than for an isolated plume element. Because the LONGZ (and SHORTZ) building source option assumes that there is no buoyant plume rise, the concentrations calculated for emissions from the Potroom complex may overestimate the concentrations that actually occur at downwind distances less than the distance at which the buoyant roof monitor emissions mix to the surface.

The source data in Table 2-13 are shown in the form required for input to LONGZ in Table 2-14. Source Type 0 refers to stacks and Source Type 1 refers to building sources. Source Type 2, which is not used in this example, applies to area sources. As shown by Table 2-14, the width and length of a building or area source are substituted for the stack exit temperature and volumetric emission rate in the LONGZ

TABLE 2-13

STACK PARAMETERS AND EMISSIONS DATA FOR THE HYPOTHETICAL ALUMINUM PLANT

Parameter	Source			
	Primary Scrubber System	Potline Roof Monitors	Carbon Baking Plant	Metal Services Building
Stack Height Above Grade (m)	60	15	30	25
Exit Temperature (^{o}K)	370	Ambient + 10	340	590
Exit Velocity (m/sec)	25	1	20	12
Number of Exit Points	1	8	1	3
Area of Exit Points (m^2)	10.7	486.4	5.3	0.9
Particulate Emission Rate (g/sec)	3.78	2.19*	0.60	0.20*

*Total emissions for all emission points.

TABLE 2-14

STACK AND PARTICULATE EMISSIONS DATA FOR THE HYPOTHETICAL ALUMINUM PLANT

Source No.	Source Type	TSP Emission Rate (g/sec)	X Coordinate (m)	Y Coordinate (m)	Stack Height (m)	Exit Temperature (^{o}K) or Width (m)	Volumetric Emission Rate (m^3/sec)or Length (m)	Stack Radius (m) or Angle δ(deg)
1	0	3.78	-350	0	60	370	267.5	1.85
2	0	0.60	-100	250	30	340	106.0	1.30
3	0	0.20	200	350	25	590	10.8	0.54
4	1	0.73	-200	0	15	200	200	0
5	1	0.73	0	0	15	200	200	0
6	1	0.73	+200	0	15	200	200	0

Source No. 1 = the Primary Scrubber System stack

Source No. 2 = the Carbon Baking Plant stack

Source No. 3 = the Metal Services Building stacks

Source Nos. 4-6 = the Potroom complex

source inputs. Similarly, the angle δ between north and the long side of a building or area source is substituted for the stack radius. Because the three stacks on the Metal Services Building are identical and in close proximity, they are represented for modeling purposes by a single stack with a particulate emission rate equal to the total for the three stacks. Source elevations are not included in Table 2-14 because the plant is assumed to be in an area of flat terrain. The source combinations of interest are:

- Source 1 - the Primary Scrubber System stack
- Source 2 - the Carbon Baking Plant stack
- Source 3 - the Metal Services Building stack
- Sources 4 through 6 - the Potroom complex
- Sources 1 through 6 - all sources within the plant

The LONGZ meteorological input requirements include seasonal STAR summaries, turbulent intensities corresponding to the Pasquill stability categories, seasonal median early morning and afternoon mixing depths, wind-profile exponents, vertical potential temperature gradients and ambient air temperatures. The STAR summaries for the example problem are based on surface weather measurements made at the Greater Pittsburgh Airport for the year 1976. The remaining meteorological inputs, which were developed following the procedures suggested in Section 2.1.1, are identical to the inputs developed by Cramer, et al. (1975) as part of the Allegheny County SO_2 study. Table 2-15 lists the vertical turbulent intensities given by Cramer, et al. (1975) for urban areas, which are also the LONGZ default values for urban areas. Table 2-16 gives the Greater Pittsburgh Airport median mixing depths. Median afternoon mixing depths are assigned to the unstable A, B and C stability categories; median early morning mixing depths are assigned to the combined stable E and F categories; and the averages of the early morning and afternoon median mixing depths are assigned to the neutral D stability category. The

TABLE 2-15

VERTICAL TURBULENT INTENSITIES USED FOR ALL SOURCE TYPES IN THE ANNUAL CONCENTRATION CALCULATIONS

Pasquill Stability Category	σ'_E (rad)
A	0.1745
B	0.1745
C	0.1080
D	0.0735
E	0.0465

TABLE 2-16

MIXING-LAYER DEPTHS IN METERS USED IN THE ANNUAL CONCENTRATION CALCULATIONS

Pasquill Stability Category	Wind-Speed Category (m/sec)					
	0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	>10.8
(a) Winter						
A	500	650	-	-	-	-
B	500	650	710	-	-	-
C	500	650	710	710	710	710
D	320	470	670	710	710	710
E	140	290	630	-	-	-
(b) Spring						
A	1530	1530	-	-	-	-
B	1530	1530	1530	-	-	-
C	1530	1530	1530	1530	1530	1530
D	825	920	1030	1415	1530	1530
E	120	310	530	-	-	-
(c) Summer						
A	1730	1730	-	-	-	-
B	1730	1730	1730	-	-	-
C	1730	1730	1730	1730	1730	1730
D	960	1025	1235	1295	1295	1295
E	190	320	740	-	-	-
(d) Fall						
A	1230	1230	-	-	-	-
B	1230	1230	1230	-	-	-
C	1230	1230	1230	1230	1230	1230
D	685	740	970	1190	1230	1230
E	140	250	710	-	-	-

ambient air temperatures and vertical potential temperature gradients are given in Tables 2-17 and 2-18, respectively. The vertical potential temperature gradients in Table 2-18 are the values suggested for humid regions in Table 2-4. The wind-profile exponents in Table 2-19 are the LONGZ default values. The wind system measurement height, the elevation of the Greater Pittsburgh Airport, the decay coefficient and the parameter ROTATE are given in Table 2-12.

The maximum annual average ground-level concentrations produced by emissions from each of the stacks of the hypothetical aluminum plant can be expected to occur within about 2 kilometers of the base of the stack. Similarly, the maximum annual average ground-level particulate concentration produced at or beyond the property boundary by the low-level emissions can be expected to occur at or near the property boundary. In order to detect the maximum annual average concentration produced at or beyond the property boundary by the combined emissions from all sources, the irregularly-spaced Cartesian receptor array {X(m) and Y(m) = 0, ±200, ±400, ±600, ±800, ±1,000, ±1,200, ±1,500, ±2,000, ±3,000} is used in the LONGZ calculations. Additionally, discrete receptors are placed at 200-meter intervals around the property boundary (see Figure 2-6). Table 2-20 gives the coordinates of the discrete receptors.

TABLE 2-17

AMBIENT AIR TEMPERATURES USED IN THE ANNUAL AVERAGE CONCENTRATION CALCULATIONS

Pasquill Stability Category	Ambient Air Temperature (°K)			
	Winter	Spring	Summer	Fall
A	273.2	287.0	298.3	289.5
B	273.2	287.0	298.3	289.5
C	273.2	287.0	298.3	289.5
D	271.2	283.7	294.4	286.3
E	269.7	280.3	290.7	282.4

TABLE 2-18

VERTICAL POTENTIAL TEMPERATURE GRADIENTS IN DEGREES KELVIN PER METER USED IN THE ANNUAL AVERAGE CONCENTRATION CALCULATIONS

Pasquill Stability Category	Wind-Speed Category (m/sec)					
	0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	> 10.8
A	0.0	0.0	--	--	--	--
B	0.0	0.0	0.0	--	--	--
C	0.0	0.0	0.0	0.0	0.0	0.0
D	0.015	0.010	0.005	0.003	0.003	0.003
E	0.030	0.020	0.015	--	--	--

TABLE 2-19

WIND-PROFILE EXPONENTS USED IN THE ANNUAL AVERAGE CONCENTRATION CALCULATIONS

Pasquill Stability Category	Wind-Speed Category (m/sec)*					
	0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	> 10.8
A	0.10	0.10	--	--	--	--
B	0.10	0.10	0.10	--	--	--
C	0.20	0.15	0.10	0.10	0.10	0.10
D	0.25	0.20	0.15	0.10	0.10	0.10
E	0.30	0.25	0.20	--	--	--

* Measurement height is 6.1 meters above the ground surface.

TABLE 2-20

COORDINATES OF DISCRETE RECEPTORS PLACED AROUND THE PROPERTY BOUNDARY OF THE HYPOTHETICAL ALUMINUM PLANT

Receptor No.	X Coordinate (m)	Y Coordinate (m)
1	-800	700
2	-600	700
3	-400	700
4	-200	700
5	0	700
6	200	700
7	400	700
8	600	700
9	800	700
10	800	500
11	800	300
12	800	100
13	800	-100
14	800	-300
15	800	-500
16	600	-500
17	400	-500
18	200	-500
19	0	-500
20	-200	-500
21	-400	-500
22	-600	-500
23	-800	-500
24	-800	-300
25	-800	-100
26	-800	100
27	-800	300
28	-800	500

SECTION 3

USER'S INSTRUCTIONS FOR THE SHORT-TERM (SHORTZ) MODEL PROGRAM

3.1 SUMMARY OF PROGRAM OPTIONS, DATA REQUIREMENTS AND OUTPUT

3.1.1 Summary of SHORTZ Program Options

The program options of the short-term computer program (SHORTZ) consist of three general categories:

- Meteorological data input options
- Dispersion-model options
- Output options

Each category is discussed separately below.

a. Meteorological Data Input Options. Table 3-1 lists the meteorological data input options for the SHORTZ computer program. All meteorological data may be input by card deck or by a previously generated tape inventory (see Section 3.1.1.c below). In addition to accepting sequential hourly meteorological data, SHORTZ accepts 2-hour average, 3-hour average, etc. meteorological data. Site-specific mixing depths, ambient air temperatures, wind speeds, wind directions and vertical potential temperature gradients are SHORTZ input requirements rather than options. If available, site specific wind-profile exponents, lateral and vertical turbulent intensities and lateral diffusion coefficients (α) may be used. Source-specific entrainment coefficients may also be used in the plume-rise calculations (see Section 2.2).

b. Dispersion-Model Options. Table 3-2 lists the dispersion model options for the SHORTZ computer program. In concentration calculations for large particulates, the effects of gravitational settling

TABLE 3-1

METEOROLOGICAL DATA INPUT OPTIONS FOR SHORTZ

Input of hourly data or of 2-hour average, 3-hour average, etc., data by card deck or from tape

Site-specific wind-profile exponents

Site-specific lateral and vertical turbulent intensities (different values may be entered for stacks and for building and area sources)

Source-specific entrainment coefficients for plume rise calculations

Wind system measurement height

TABLE 3-2

DISPERSION-MODEL OPTIONS FOR SHORTZ

Inclusion of effects of gravitational settling and dry deposition in concentration calculations

Inclusion of terrain effects

Cartesian or polar receptor system

Discrete receptors (Cartesian or polar system)

Stack, building and area sources

Pollutant emission rates and stack exit parameters held constant or varied by hour

Time-dependent exponential decay of pollutants

Time periods for which concentration calculations are to be made and dry deposition may be included in the calculations for areas of open terrain, but not for areas of complex terrain. With this exception, terrain effects may be included in all SHORTZ calculations. The user may select either a Cartesian or a polar receptor system and may also input discrete receptor points with either system. SHORTZ calculates concentrations for stack, building and area source emissions. Pollutant emission rates may be held constant or varied by hour. The effects of time-dependent exponential decay of a pollutant as a result of chemical transformation or other removal processes may also be included in the model calculations (see Section 2.3). Also, the user may select the time periods over which concentration is to be averaged. These time periods range from 1 hour to 8784 hours (i.e., a leap year).

c. Output Options. Table 3-3 lists the SHORTZ program output options. A more detailed discussion of the SHORTZ output information is given in Section 3.1.3.

The results of all SHORTZ calculations, as well as all input data, may be stored on magnetic tape. The user may also elect to print one or more of the following tables:

- The program control parameters, source data and receptor data
- The meteorological inputs
- The concentrations calculated for the averaging time of the meteorological data (for example, 3-hour average concentrations if the meteorological inputs are assumed to represent 3-hour averages) for any desired combinations of sources at all receptors

TABLE 3-3

SHORTZ OUTPUT OPTIONS

Master tape inventory of meteorological and source inputs and the results of the concentration calculations

Printout of program control parameters, source data and receptor data

Printout of meteorological data

Printout of the concentrations calculated for any desired combinations of sources at all receptors

Printout of concentrations calculated for the averaging time of the meteorological data and for up to three additional averaging times

- The average concentrations calculated for one, two or three user-specified averaging times in addition to the averaging time of the meteorological inputs for any desired combinations of sources at all receptors

It should be noted that a given problem run may generate a large print output (see Section 3.2.5.b). Consequently, it may be more convenient to make multiple program runs for a given problem.

3.1.2 Data Input Requirements

This section provides a description of all input data parameters required by the SHORTZ program. The user should note that some input parameters are not read or are ignored by the program, depending on what values control parameters have been assigned by the user.

a. Program Control Parameter Data. These data contain parameters which provide user-control of all program options.

Parameter Name	
ISW(1)	Input Meteorological Data Base Rate -- This parameter gives the number of hours in each input meteorological data observation (i.e., the assumed averaging time of the meteorological inputs). If this parameter is not punched or has a value of "0", the program uses (defaults to) a value of "1" and assumes hourly input data. This parameter is ignored by the SHORTZ program if an input source/concentration inventory tape is being used.
ISW(2)	Print Concentration Calculated at Meteorological Data Base Rate -- This parameter provides the option to print the ground-level concentrations calculated for each input meteorological observation. If this parameter is not

Parameter Name	
ISW(2) (Cont.)	punched or is set to a value of "0", these concentration calculations are not printed. If set to a value of "1", concentrations calculated at the data base input rate are printed.
ISW(3)	Print Average Concentration Option 1 -- This parameter specifies the first averaging time desired for the concentration calculations. If this parameter is not punched or is set to a value of "0", this option is ignored by the program.
ISW(4)	Print Average Concentration Option 2 -- This parameter specifies the second averaging time desired for the concentration calculations. If this parameter is not punched or is set to a value of "0", this option is ignored. However, if this option is punched greater than zero, the value punched must be greater than that punched for ISW(3) and ISW(3) must be non-zero.
ISW(5)	Print Average Concentration Option 3 -- This parameter specifies the third averaging time desired for the concentration calculations. If this parameter is not punched or is set to a value of "0", this option is ignored. However, if this option is punched greater than zero, the value punched must be greater than that punched for ISW(4) and ISW(4) must be non-zero.
ISW(6)	Print Input Control and/or Source Data -- This parameter is used to control the printing of the input control and source data. If this parameter is not punched or is set to a value of "0", control and source data are not printed.

Parameter Name	
ISW(6) (Cont.)	If set to a value of "1", only the control and general input data are printed. If set to a value of "2", only source data are printed. If set to a value of "3", both control and source data are printed.
ISW(7)	Receptor Terrain Elevation Option — Allows the user to input terrain elevations for all receptor points. A value of "1" directs the program to read user-provided terrain elevations. A value of "0" assumes level terrain and no terrain elevations are read by the program. The default value equals "0".
ISW(8)	Print Meteorological Data Option -- This option controls the printing of the input meteorological data. A value of "1" directs the program to print all of the input meteorological data. If this parameter is not punched or is set to a value of "0", this option is ignored.
ISW(9)	Wind Speed Power Law Option -- If a value of "0" is used, the wind-speed power law is based on emission elevation above the airport (weather station) elevation. If the emission elevation is below the airport (weather station), no power law is used. If a value of "1" is used, the wind speed power law is based on the emission height above terrain and a power law is always used. If this parameter is not punched, the program will default to a value of "0".
ISW(10)	Print Output Unit Option -- This option is provided to enable the user to print the program output on a unit other than print unit "6". If this value is not punched or a "0" is punched, all print output goes to unit "6". Otherwise, print output goes to the specified unit. Also,

Parameter Name	
ISW(10) (Cont.)	if this value is punched and not equal to "6" or "56", two end-of-file marks are written at the end of the print file and the file is rewound.
ISW(11)	Average Over Days or Cases Option -- This option is provided to enable the user to calculate the average N-hour concentrations for particular time(s) of day over multiple days or cases. If this parameter is not punched or is set to a value of "0", this option is ignored. However, if set to a value of "1", the program will calculate the concentrations over the averaging times specified by ISW(2) through ISW(5) for each day or case (NDAYS) of the meteorological data. The program will then average the days or cases together. For example, assume that 3-hour average concentrations are being calculated and that the first hour of each day is 0000 hours. The program would print the average concentration for the period 0000 to 0200 hours (0300-0500, 0600-0800, etc.) averaged over the days or cases (NDAYS) input. As another example, this option could be used to calculated 7-day average concentrations by averaging the 24-hour average concentrations calculated for the individual days.
ISW(12)	Optional Format for Source Card Input Data -- This parameter is a switch used to inform the program whether it is to use a default format to read the card input source data or to input the format via data card. If this option is not punched or is "0", the program uses the default format given under SFMT below and SFMT is not input to the program. If this option is set to a value of "1", the array SFMT below is read by the program.

Parameter Name	
ISW(13)	Receptor Reference Grid System Option -- Specifies whether a right-handed rectangular Cartesian coordinate system or a polar system is to be input to the program to form the receptor reference grid system. A value of "0" indicates a Cartesian reference grid system is being input and a value of "1" indicates a polar reference grid system is being input. If this parameter is not punched, the program will default to a value of "0".
ISW(14)	Discrete Receptor Option - Specifies whether a right-handed rectangular Cartesian reference system or polar reference system is used to reference the input discrete receptor points. A value of "0" indicates that the Cartesian reference system is being used and a value of "1" indicates a polar reference system is being used. If this parameter is not punched, the program will default to a value of "0".
ISW(15)	Source Coordinates Option -- Specifies whether a right-handed rectangular Cartesian reference system or polar reference system is used to reference the input source coordinates. A value of "0" indicates that the Cartesian reference system is used and a value of "1" indicates a polar reference system is used. If this parameter is not punched, the program will default to a value of "0".
ISW(16)	Turbulent Intensities Option -- This option allows the user to enter different turbulent intensities for stacks and for building and area sources. If this parameter is not punched or is "0", the program uses the same turbulent intensities (SIGEPU and SIGAPU) for all source types. If

Parameter Name	
ISW(16) (Cont.)	ISW(16) equals "1", different turbulent intensities are entered for stacks (SIGEPU and SIGAPU) and for area and building sources (SIGEPL and SIGAPL). No default turbulent intensities are provided if ISW(16) equals "1". The default value for the parameter ISW(16) is "0", or the same turbulent intensities for all source types.
ISW(17)	Rural/Urban Mode Option -- If the Turbulent Intensities Option is not used (*i.e.*, if ISW(16) equals "0"), this option directs the program to use the Cramer, *et al.* (1975) rural or urban turbulent intensities corresponding to the Pasquill stability categories as default values for all source types. The program uses the rural turbulent intensities as default values if ISW(17) equals "0" and the urban turbulent intensities as default values if ISW(17) equals "1". The default value for the parameter ISW(17) is "0". It should be emphasized that the program will not use default turbulent intensities if the parameter ISW(16) above equals "1" and only uses default values if SIGAPU and SIGEPU are equal to "0" or are not punched.
ISW(18) - ISW(20)	Reserved for Future Options.
NSOURC	Number of Data Card Input Sources - This parameter specifies the number of input card image sources. This includes card images that specify modifications or deletions to sources input from tape file. If this value is not punched or is "0", the program assumes all sources are input from tape. The maximum number of sources (both card and tape) that can be processed by the program in a

Parameter Name	
NSOURC (Cont.)	single run is 300. However, this number can be increased by a simple program modification given in Section 3.2.3.a under Card Group 2.
NGROUP	Number of Source Combination Groups - This parameter specifies the number of different source combinations for which print output is desired. A source combination consists of one or more of all the input sources and is the summed output of those selected sources. The maximum value for this parameter is 1000. If this parameter is not punched or is "0", the program assumes that all input sources (card and/or tape) are to be used in one combined source output. Also, if this parameter is not punched or is "0", the associated parameter arrays NSOGRP and IDSOR below are not read by the program and can be ignored.
NXPNTS	X-Axis/Range Receptor Grid Size -- This parameter specifies the number of east-west receptor grid locations for the Cartesian coordinate system X-axis, or the number of receptor grid ranges (rings) in the polar coordinate system, depending on which receptor grid system is chosen by the user under parameter ISW(13). This is the number of X-axis points to be input or the number of X-axis points to be automatically generated by the program. A value of "0" (not punched) directs the program to assume there is no regular receptor grid being used. The maximum value of this parameter is related to other parameter values and is given by the equation $E \geq \left[N_x+N_y+2N_{xy}\right] + \left[6 \cdot (N_x \cdot N_y+N_{xy})\right] \qquad (3\text{-}1)$

Parameter Name

where

E = the total amount of program data storage in BLANK COMMON. The design size is 12000, but can be increased by a simple program modification given in Section 3.2.3.a under Card Group 2.

N_x = number of points in the input X-axis of the receptor grid system (NXPNTS)

NXPNTS (Cont.)

N_y = number of points in the input Y-axis of the receptor grid system (NYPNTS)

N_{xy} = number of discrete (arbitrarily placed) input receptors (NXWYPT)

This parameter is ignored by the program if tape input is being used.

NYPNTS

Y-Axis/Azimuth Receptor Grid Size -- This parameter specifies the number of north-south receptor grid locations for the Cartesian coordinate system Y-axis, or the number of Y-axis azimuth bearings in the polar coordinate system, depending on which receptor grid system is chosen by the user under parameter ISW(13). This is the number of Y-axis points to be input or the number of Y-axis points to be automatically generated by the program. If the parameter NXPNTS is set non-zero, the parameter

Parameter Name	
NYPNTS (Cont.)	NYPNTS must also be non-zero. The maximum value of this parameter is given by the equation under NXPNTS above. The parameter NYPNTS is ignored by the program if tape input is being used.
NXWYPT	Number of Discrete (Arbitrarily Placed) Receptors -- This parameter specifies the total number of discrete receptor points to be input to the program. A value of "0" (not punched) directs the program to assume no discrete receptors are being used. The maximum value of this parameter is limited by the equation given under NXPNTS above. This parameter is ignored by the program if input tape is being used. ISW(14) specifies whether these points are in Cartesian or polar coordinates.
NHOURS	Number of Input Meteorological Data Observations -- This parameter specifies the total number of input meteorological data observations. For example, if the input meteorological data are hourly, this parameter specifies the total number of hours. Similarly, if 3-hour average meteorological data are input, NHOURS specifies the total number of 3-hourly observations the program is to read. The maximum value of NHOURS is "8784" and the default value is "24" if this parameter is not punched or is "0".
NDAYS	Number of Days or Cases of Meteorological Data -- This parameter specifies the number of separate days or cases of meteorological data to be processed. If this option is used, the program expects to read NDAYS sets of meteorological data with NHOURS observations (data cards) in each set. Each case is treated as if it was an individual

Parameter Name	
NDAYS (Cont.)	program run, except when the ISW(11) option is used. If an output tape is being used, the calculations for each case are output successively to the tape.
KSW	Master Source/Concentration Magnetic Tape Input/Output Option -- This option specifies whether or not input and/or output tapes are going to be used. A value of "0" indicates neither tape input nor tape output is being used. A value of "1" indicates tape input is being used and the tape data are read from the logical units specified by the array NINFL below. A value of "2" indicates tape output is desired and the tape data are written to the logical units specified by the array NOTFL below. A value of "3" specifies both tape input and output are going to be used.
NINTP	Number of input tapes -- This parameter gives the number of input magnetic tapes when the KSW equals "1" or "2" option is selected. If this parameter is not punched or is set to a value of "0", the program defaults to a value of "1". The maximum for this parameter is "3".
NOTTP	Number of Output Tapes -- This parameter gives the number of output tapes the user has provided when the KSW equals "2" or "3" option is selected. If this parameter is not punched or is set to a value of "0", the program defaults to a value of "1". The maximum for this parameter is "3".
NINFL	Input Tape Logical Unit Numbers -- This parameter is an array of a maximum of three logical unit numbers used for magnetic tape input. If the values in this array are not punched or are set to values of "0", the program defaults

Parameter Name	
NINFL (Cont.)	the values to "2", "0" and "0", respectively. The user must equate the logical unit numbers specified here with the external file name assigned to the tape as shown in Section 3.2.2. Values input to this array must be compatible with the UNIVAC 1100 NTRAN I/O routines. Do not use the values 0, 1, 5, 6 or 12 for this parameter.
NOTFL	Output Tape Logical Unit Numbers -- This parameter is an array of a maximum of three logical unit numbers used for magnetic tape output. If the values in this array are not punched or are set to values of "0", the program defaults to values of "3", "0" and "0", respectively. The user must equate the logical unit numbers specified here with the external file name assigned to the tape as shown in Section 3.2.2. Values input to this array must be compatible with the UNIVAC 1100 NTRAN I/O routines. Do not use the values 0, 1, 5, 6 or 12 for this parameter.
NSOGRP	Number of Sources Defining Combined Source Groups -- This parameter is not read by the program if the parameter NGROUP above is zero or not punched. Otherwise, this parameter is an array of NGROUP values, where each value gives the number of source identification numbers used to define a source combination. The source identification number is that number assigned to each source by the user under the source input parameter NUMSQ below. An example and a more detailed discussion of the use of this parameter is given under IDSOR below. A maximum of 1000 values are provided for this array.
IDSOR	Combined Source Group Defining Sources -- This parameter is not read by the program if the parameter NGROUP above is

Parameter Name

IDSOR (Cont.)

zero or not punched. Otherwise, this parameter is an array of source identification numbers that define each combined source group to be output. The values punched into the array NSOGRP above indicate how many source identification numbers are punched into this array successively for each combined source output. The source identification numbers can be punched in two ways. The first is to punch a positive value directing the program to include that specific source in the combined output. The second is to punch a negative value. When a negative value is punched, the program includes all sources with identification numbers less than or equal to it in absolute value. Also, if the negative value is preceded by a positive value in the same defining group, that source defines the first of the sources to be included with those defined by the negative number, but no sources with a lesser source identification number are included. For example, assume NGROUP above is set equal to 4 and the array NSOGRP contains the values 3, 2, 1, 0. Also, assume the entire set of input sources is defined by the source identification numbers 5, 72, 123, 223, 901, 902, 1201, 1202, 1205, 1206 and 1207. To this point we have a total of 11 input sources and we desire to see 4 combinations of sources taken from these 11. Also, the array NSOGRP indicates that the first 3 values in the array IDSOR define the first source combination, the next 2 values (4th and 5th) in IDSOR define the second combination, the 6th value in IDSOR defines the third combination and the last combination has no defining (0) sources so the program assumes all 11 sources are used. Similarly, let the array IDSOR be set equal to the values 5, 72, -223, 1201-1207, -902.

Parameter Name	
IDSOR (Cont.)	The program will first produce combined source output for sources 5, 72 and all sources up to and including 223. The second combined source output will include sources 1201 through 1207. The third will include sources numbers 5 through 902 and the last will include all sources input. Note that the source identification numbers in each defining group are in ascending order of absolute value. The maximum number of values that can be input to this array is 1000.
SFMT	Optional Format for Source Data -- This parameter is an array which is read by the program only if ISW(12) is set to a value of "1". The array SFMT is used to specify the format used for the input card source data. The format punched, if used, must include leading and ending parentheses. If ISW(12) is not punched or is set to a value of "0", the parameter SFMT is omitted from the input deck and the program uses the default format "(I5, 3I1, F10.0, 8F7.0, I2)". This format is used to read the variables - NUMSQ, TYPE, DISP, JFLG, Q, DX, DY, H, HS, TS, VOL, DTH, RDS and NS. These parameters are the primary source inputs and are defined under the source input data below.

b. Receptor Data. These data consist of the (X,Y) or (range, azimuth) locations of all receptor points as well as the elevations of the receptors above mean sea level.

Parameter Name	
X	Receptor Grid System X-Axis or Range -- This parameter is read by the program only if the parameters NXPNTS and

Parameter Name	
X (Cont.)	NYPNTS are non-zero and only if an input tape is not being used. This parameter is an array of values in ascending order that defines the X-axis or ranges (rings) (depending on ISW(13)) of the receptor grid system in meters. If only 2 values are punched and the parameter NXPNTS is greater than 2, the program assumes the X-axis (range) is to be generated automatically and assumes the first value is the starting X coordinate and the second value is an increment used to generate the remaining NXPNTS evenly-spaced X coordinates. If all receptor points are being input, NXPNTS values must be punched. The origin of the grid system is defined by the user and can be anywhere.
Y	Receptor Grid System Y-Axis or Azimuth -- This parameter is read by the program only if the parameters NXPNTS and NYPNTS are non-zero and only if an input tape is not being used. This parameter is an array of values in ascending order that defines the Y-axis or azimuth bearings measured clockwise from zero degrees (north) (depending on ISW(13)) of the receptor grid system in meters or degrees. If only 2 values are punched and the parameter NYPNTS is greater than 2, the program assumes the first value is the starting Y coordinate and the second value is the increment used to generate the remaining NYPNTS evenly-spaced (rectangular or angular) Y coordinates. If all receptor points are being input, NYPNTS values must be punched. If polar coordinates are being used, Y is measured clockwise from zero degrees (north).
X (Discrete)	Discrete (Arbitrarily Placed) Receptor X or Range -- This parameter is not read by the program if the parameter NYWYPT is zero or if the program is using an input tape.

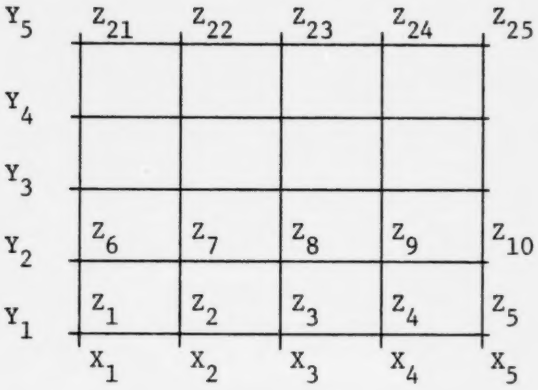
Parameter Name	
X (Discrete) (Cont.)	This parameter is an array defining all of the discrete receptor X points. The values are either east-west distances or radial distances in meters, depending on the type of reference system specified by ISW(14). NXWYPT points are read by the program. The origin of these points is the same as the origin of the regular (non-discrete) grid system if one is used. Otherwise, the origin is defined by the user and can be located anywhere.
Y (Discrete)	Discrete (Arbitrarily Placed) Receptor Y or Azimuth -- This parameter is not read by the program if the parameter NXWYPT is zero or if the program is using an input tape. This parameter is an array defining all of the discrete receptor Y points in meters or degrees. The values are either north-south distances or azimuth bearings (angular distances) measured clockwise from zero degrees (north) depending on the type of reference system specified by ISW(14). NXWYPT points are read by the program.
ZZ	Elevation of Grid System Receptors -- This parameter is not read by the program if the parameter ISW(7) is zero or if an input tape is being used or if NXPNTS or NYPNTS equals zero. This parameter is an array specifying the terrain elevation in meters above mean sea level at each receptor of the Cartesian or polar grid system. There are NXPNTS•NYPNTS values read into this array. The program starts the input of values with the first Y coordinate specified and reads the elevations for each X coordinate at that Y in the same order as the X coordinates were input. A new data card is started for each successive Y coordinate value and the NXPNTS elevations for that Y are read. The program will expect NYPNTS groups of data

Parameter
Name

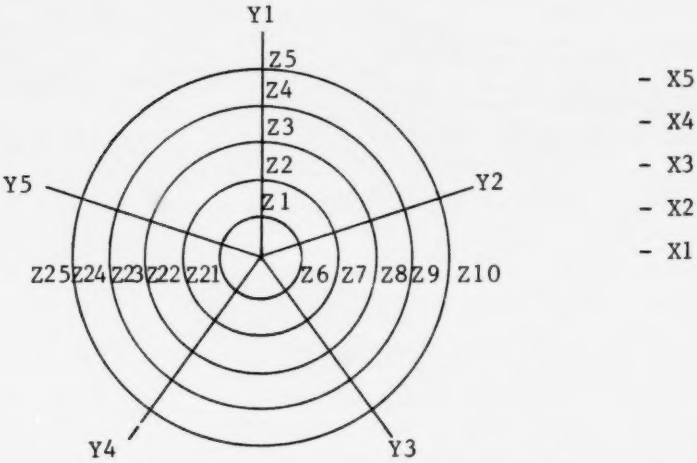
ZZ
(Cont.)

cards with NXPNTS elevation values punched in each group. For example, assume we have a 5-by-5 Cartesian or polar receptor array:

Rectangular


Y_5
Z_{21}
Z_{22}
Z_{23}
Z_{24}
Z_{25}
Y_4
Y_3
Y_2
Z_6
Z_7
Z_8
Z_9
Z_{10}
Y_1
Z_1
Z_2
Z_3
Z_4
Z_5
X_1
X_2
X_3
X_4
X_5

Polar


Y1
Z5
Z4
Z3
Z2
Z1
- X5
- X4
- X3
- X2
- X1
Y5
Y2
Z25
Z24
Z23
Z22
Z21
Z6
Z7
Z8
Z9
Z10
Y4
Y3

The values Z_1 through Z_5 are read from the first card group, the values Z_6 through Z_{10} from the second card group and Z_{21} through Z_{25} from the last card group.

Parameter Name	
ZZ (Discrete)	Elevation of the Discrete (Arbitrarily Placed) Receptors -- This parameter is not read by the program if the parameter ISW(8) is zero or if the parameter NXWYPT equals zero or if an input tape is being used. This parameter, which is an array specifying the terrain elevation in meters at each of the NXWYPT discrete receptors, is input in the same order as the discrete receptors.

c. Identification Labels and Model Constants. These data consist of parameters pertaining to heading and identification labels and program constants. These data, except for TITLE, are ignored by the program if an input tape is being used.

Parameter Name	
TITLE	Page Heading Label -- This parameter is an array that allows up to 79 characters of title information to be printed as the first line of each output page.
KUNR	Concentration Units Label -- This parameter is an array used for the optional input of the concentration units label. There are a maximum of 24 characters provided for an optional output units label for concentration. This label is defaulted to "(micrograms/cubic meter)" for concentration if the parameter TK below is not punched or is "0".
KFNR	Source Units Label -- This parameter is a 12 character array provided for an optional source input units label. This label is defaulted to "(grams/second)" if the parameter TK below is not punched or is "0".

Parameter Name	
ROTATE	Wind Direction Correction Angle -- This parameter is used to correct for any difference between north as defined by the X, Y reference grid system and north as defined by the weather station at which the wind direction data were recorded. The value of ROTATE (degrees) is subtracted from each wind-direction angle (THETA). This parameter is positive if the positive Y axis of the reference grid system points to the right of north as defined by the weather station. Most weather stations record direction relative to true north and the center of most grid systems are relative to true north. However, some weather stations record direction relative to magnetic north and the ends of some UTM (Universal Transverse Mercator) zones are not oriented towards true north. The user is cautioned to check the wind data as errors in the wind direction distribution will lead to erroneous program results.
TK	Model Units Conversion Factor -- This parameter is provided to give the user flexibility in the source input units used and the concentration output units desired. This parameter is a direct multiplier of the concentration equation. If this parameter is not punched or is set to a value of "0", the program defaults to "1×10^6" micrograms per gram. This default assumes the user desires concentration in micrograms per cubic meter and the input source units are grams per second. Also, if the default value for this parameter is selected, the program defaults the units labels in the array KUNR and KFNR above. If the user chooses to input this parameter for other units, he must also input the units labels in KUNR and KFNR above. This parameter corresponds to K in Equations (2-8), (2-24) and (2-29).

Parameter Name	
HA	Station Elevation -- This parameter gives the elevation of the airport or weather station in meters and is read only if terrain elevations are input for the receptor points.
UTMX	X-Origin of Polar Reference System -- This parameter gives the east-west Cartesian coordinate of the origin of the polar reference system and/or discrete polar coordinates. If polar coordinates are not used, this parameter is ignored. If this parameter is not punched or a value of "0" is used, all polar coordinates are relative to zero and the polar coordinates are printed. However, if this parameter is set to a non-zero value, all polar coordinates are relative to this Cartesian X coordinate and the program converts all discrete polar coordinate points to their respective Cartesian coordinates for the calculation and print output of concentration tables.
UTMY	Y-Origin of the Polar Reference System -- This parameter gives the north-south Cartesian coordinate of the origin of the polar reference system and/or discrete polar coordinates. If polar coordinates are not used, this parameter is ignored. If this parameter is not punched or a value of "0" is used, all polar coordinates are relative to zero and the polar coordinates are printed. However, if this parameter is set to a non-zero value, all polar coordinates are relative to this Cartesian Y coordinate and the program converts all discrete polar coordinate points to their respective Cartesian coordinates for the calculation and print output of concentration tables.

Parameter Name	
G	Acceleration Due to Gravity -- This parameter, which is used in the plume rise calculations, is the acceleration due to gravity. If this parameter is not punched or has a value of "0", the program uses "9.8" meters per second squared as the default value. This parameter corresponds to g in Equation (2-4).
ZR	Weather Station Recording Height -- This parameter is the height above ground level in meters at which the meteorological data were recorded. If this parameter is not punched or has a value of "0", the program defaults to "6.1" meters. This parameter corresponds to Z_R in Equation (2-13).
GAMMA1	Adiabatic/Unstable Entrainment Coefficient -- This parameter, which is used in plume rise calculations, is the air entrainment coefficient for an adiabatic or unstable atmosphere. If this value is not punched or is "0", the program uses "0.6" as the default value. This parameter corresponds to γ_1 in Equation (2-3).
GAMMA2	Stable Entrainment Coefficient -- This parameter, which is used in the plume rise calculations, is the air entrainment coefficient for a stable atmosphere. If this value is not punched or is "0", the program uses "0.66" as the default value. This parameter corresponds to γ_2 in Equation (2-7).
DECAY	Decay Coefficient -- This parameter is the coefficient (seconds^{-1}) of time-dependent pollutant removal by physical or chemical processes (Equation (2-12)). The default for this parameter is "0".

Parameter Name	
XRY	Rectilinear Plume Expansion Distance -- This parameter is the distance in meters over which rectilinear lateral plume expansion occurs downwind from an ideal point source. If this parameter is not punched or is "0", the program assumes "50" meters.

d. Meteorological Data. These data are the meteorological input parameters. Each meteorological parameter value is a 1-hour, 2-hour, etc. average value depending on ISW(1). These parameters are not read by the program if an input tape is being used.

Parameter Name	
HOUR	Observation Hour -- The hour (00-23 or 0000-2300) of the meteorological observation.
THETA	Wind Direction -- The direction from which the wind is blowing in degrees (no default).
UBAR	Wind Speed -- The wind speed in meters per second (no default).
HM	Mixing Layer Depth -- The depth of the surface mixing layer in meters (no default).
TA	Ambient Air Temperature -- The ambient air temperature in degrees Kelvin (no default).
DPDZ	Vertical Gradient of Potential Temperature -- The vertical gradient of potential temperature in degrees Kelvin per meter (no default).

Parameter Name	
ISTBLE	Stability Category -- The Pasquill stability category - A, B, C, D, E or F. This parameter is used only to select default values for those meteorological parameters not punched or equal to zero for which default values are provided (P, SIGEPU, SIGEPL, SIGAPU, SIGAPL).
P	Wind Speed Power Law Exponent -- The wind speed power law exponent. A default value is provided for P only if ISTBLE is specified. The default values for P depend on the wind speed and stability categories and are shown in Table 3-4.
SIGAPU	Lateral Turbulent Intensity for Stack Sources -- The standard deviation of the wind direction angle in radians or degrees for stack sources. No default values are provided for SIGAPU if the parameter ISW(16) equals "1". If the value input is greater than or equal to "1", the program assumes the units are degrees; otherwise, radians are assumed.
SIGEPU	Vertical Turbulent Intensity for Stack Sources -- The standard deviation of the wind elevation angle in radians or degrees for stack sources. No default values are provided for SIGEPU if the parameter ISW(16) equals "1". If the value input is greater than or equal to "1", the program assumes the units are degrees; otherwise, radians are assumed.
SIGAPL	Lateral Turbulent Intensity for Building or Area Sources -- The standard deviation of the wind direction angle in radians or degrees for building or area sources. If the

TABLE 3-4

DEFAULT VALUES FOR THE SHORTZ METEOROLOGICAL PARAMETERS

	Pasquill Stability Category	Wind Speed (UBAR in m/sec)					
		0 - 1.5	1.6 - 3.0	3.1 - 5.1	5.2 - 8.2	8.3 - 10.8	> 10.8
		- SIGEPU -					
RURAL MODE (ISW(16)= "0" and ISW(17)="0")	A	.1745	.1745	.1745	.1745	.1745	.1745
	B	.1080	.1080	.1080	.1080	.1080	.1080
	C	.0735	.0735	.0735	.0735	.0735	.0735
	D	.0465	.0465	.0465	.0465	.0465	.0465
	E	.0350	.0350	.0350	.0350	.0350	.0350
	F	.0235	.0235	.0235	.0235	.0235	.0235
URBAN MODE (ISW(16)= "0" and ISW(17)="1")	A	.1745	.1745	.1745	.1745	.1745	.1745
	B	.1745	.1745	.1745	.1745	.1745	.1745
	C	.1080	.1080	.1080	.1080	.1080	.1080
	D	.0735	.0735	.0735	.0735	.0735	.0735
	E	.0465	.0465	.0465	.0465	.0465	.0465
	F	.0465	.0465	.0465	.0465	.0465	.0465
		- SIGAPU -					
RURAL MODE (ISW(16)= "0" and ISW(17)="0")	A	.2495	.2495	.2495	.2495	.2495	.2495
	B	.1544	.1544	.1544	.1544	.1544	.1544
	C	.1051	.1051	.1051	.1051	.1051	.1051
	D	.0665	.0665	.0665	.0665	.0665	.0665
	E	.0501	.0501	.0501	.0501	.0501	.0501
	F	.0336	.0336	.0336	.0335	.0336	.0336

TABLE 3-4 (Continued)

	Pasquill Stability Category	Wind Speed (UBAR in m/sec)					
		0 - 1.5	1.6 - 3.0	3.1 - 5.1	5.2 - 8.2	8.3 - 10.8	> 10.8
URBAN MODE (ISW(16) = "0" and ISW(17)="1"	- SIGAPU -						
	A	.2495	.2495	.2495	.2495	.2495	.2495
	B	.2495	.2495	.2495	.2495	.2495	.2495
	C	.1544	.1544	.1544	.1544	.1544	.1544
	D	.1051	.1051	.1051	.1051	.1051	.1051
	E	.0665	.0665	.0665	.0665	.0665	.0665
	F	.0665	.0665	.0665	.0665	.0665	.0665
	- P -						
	A	.10	.10	.10	.10	.10	.10
	B	.15	.10	.10	.10	.10	.10
	C	.20	.15	.10	.10	.10	.10
	D	.25	.20	.15	.10	.10	.10
	E	.30	.25	.20	.15	.10	.10
	F	.40	.30	.20	.15	.10	.10

Parameter Name	
SIGAPL (Cont.)	value input is greater than or equal to "1", the program assumes the units are degrees; otherwise, radians are assumed. The default values given in Table 3-4 for SIGAPU are also the SIGAPL default values if the parameter ISW(16) equals "0". No default values are provided for SIGAPL if ISW(16) equals "1".
SIGEPL	Vertical Turbulent Intensity for Building or Area Sources -- The standard deviation of the wind elevation angle in radians or degrees for building or area sources. If the value input is greater than or equal to "1", the program assumes the units are degrees; otherwise, radians are assumed. The default values given in Table 3-4 for SIGEPU are also the SIGEPL default values if the parameter ISW(16) equals "0". No default values are provided for SIGEPL if ISW(16) equals "1".
ALPHA	Lateral Diffusion Coefficient -- The lateral diffusion coefficient α. The default for this parameter, if not punched or equal to "0", is "0.9".

e. Source Data. These data consist of all necessary information required for each source. These data are divided into three groups: (1) parameters that are required for all source types, (2) parameters that are required for stack type sources, and (3) parameters that are required for building sources and area sources. The order of input of these parameters is given at the end of this section. These data are not read by the program if NSOURC equals "0".

Parameter Name	
NUMSQ	Source Identification Number -- This parameter is the source identification number and is a 1 to 5 digit integer. This number cannot be defaulted and has a maximum value of 20000. Sources must be input in ascending order, of the source identification number, but source numbers need not necessarily be continuous.
DISP	Source Disposition -- This parameter is a flag that tells the program what to do with the source. If this parameter is not punched or has a value of "0", the program assumes this is a new source for which concentrations are to be calculated. Also, if the program is using an input tape, this new source will be merged into the old sources from tape or will replace a tape source with the same source identification number. If the parameter DISP has a value of "2", the program assumes that the tape input source having the same source identification number is to be deleted from the source inventory. The program removes the source as well as the concentration array for the source. If the parameter DISP has a value of "1", the program assumes the source strengths to be read from data card for this source are to be used to rescale the concentration values of the tape input source with the same source identification number. The new source strengths input from card replace the old values taken from the input tape and the concentration arrays taken from tape are multiplied by the ratio of the new and old source strengths.
TYPE	Source Type -- This parameter is a flag that tells the program what type of source is being input. If this parameter is not punched or is "0", the program assumes a stack source. If this parameter has a value of "1", the

Parameter Name	
TYPE (Cont.)	program assumes a building source. Similarly, if this parameter has a value of "2", an area source is assumed.
JFLG	Variable or Constant Emission Rate -- This parameter is used to inform the program of whether constant or variable emission rates are going to be used for the particular source. If this parameter is not punched or is set to a value of "0", the program assumes a constant emission rate for this source and reads the emission rate into Q below. If this parameter is set equal to "1", the program assumes the source emission varies with each meteorological observation input. After each meteorological observation has been read by the program, the emission rate for this source and all others with JFLG = "1" are read into QB below. Also, the stack gas exit temperature (TSB) and volumetric emission rate (VOLB) can be varied along with the pollutant emission rate by inputing these parameters along with QB.
DX	Source X Coordinate -- This parameter gives the Cartesian X (east-west) or polar coordinate (range), depending on ISW(15), of the source location in meters (X in Table 2-9) relative to the origin of the reference grid system being used. If DX is the range in polar coordinates and UTMX, UTMY above are greater than "0", DX is relative to the point (UTMX, UTMY).
DY	Source Y Coordinate -- This parameter gives the Cartesian Y (north-sourth) or polar coordinate (azimuth bearing), depending on ISW(15), of the source location in meters or degrees (Y in Table 2-9) relative to the origin of the reference grid system being used. If DX is the azimuth

Parameter Name	
DY (Cont).	bearing in polar coordinates and UTMX, UTMY above are greater than "0", DY is relative to the point (UTMX, UTMY).
H	Height of Emission -- This parameter gives the height above ground in meters of the pollutant emission. For building sources, this is the height of the building. For area sources, this is the characteristic height.
HS	Source Elevation -- This parameter gives the terrain elevation in meters above mean sea level at the source location and is not used by the program unless receptor terrain elevations (ISW(7)) are being used.
Q	Source Emission Rate -- This parameter gives the source emission rate in mass per unit time for the source NUMSQ. If JFLG above is "0", this parameter is used as a constant emission rate for the duration of the run. If JFLG is equal to "1", this parameter is ignored and the emission rate is input to QB below. The default emission rate units are grams per second. It is important to note that the program assumes a source emission rate of "0" to be a valid emission rate.
NUMSQB	Source Identification Number for Variable Emission Sources -- This parameter is the source number (NUMSQ above) of a particular source with variable emission rates (JFLG above). This parameter is read by the program only if JFLG above is equal to "1". This parameter is input to the program for each meteorological data observation and each source (NUMSQ above) with the parameter JFLG equal to "1".

Parameter Name	
QB	Alternate Variable Emission Rate -- This parameter is read by the program only if JFLG above is equal to "1". This parameter is input to the program for each meteorological data observation and gives the source emission rate for the respective meteorological period for the source number specified by NUMSQB.
NS	Number of Particulate Size Categories -- This parameter gives the number of particulate size categories in the particulate distribution used in calculating ground-level concentration with deposition occurring. The program assumes complete retention of the particulates at the ground surface with deposition occurring. If the parameter NS is greater than zero, the program reads NS values for each of the parameter variables VS and FRQ below. The maximum value of NS is 20.
VS	Settling Velocity -- This parameter array is read only if NS above is greater than zero. This parameter is the settling velocity in meters per second for each particulate size category (1 through NS). No default values are provided for this parameter.
FREQ	Mass Fraction of Particles -- This parameter array is read only if NS above is greater than zero. This parameter is the mass fraction of particulates contained in each particulate size category (1 through NS). No default values are provided for this parameter.

Stack Source Parameters

TS

Stack Gas Exit Temperature -- This parameter gives the stack gas exit temperature (T_s in Table 2-9) in degrees Kelvin. If this parameter is negative or zero, its absolute value is added to the ambient air temperature to form the stack gas exit temperature. For example, if the stack gas exit temperature is 15 degrees Celsius above the ambient temperature, enter TS as "-15".

VOL

Volumetric Emission Rate -- This parameter gives the volumetric emission rate in actual cubic meters per second. The volumetric emission rate is given by the product of the stack exit velocity and the area of the emission point. The program assumes zero plume rise if VOL equals "0".

RDS

Stack Radius -- This parameter gives the inner stack radius in meters and no default is provided. This parameter is used to calculate a correction factor f (Equation (2-5)) that accounts for downwash restrictions on buoyant plume rise. If RDS is set equal to "0", the program assumes that f is always equal to unity (*i.e.*, no downwash). If RDS is greater than "0" and the stack exit velocity is greater than or equal to 1.5 times the mean wind speed at stack height, the correction factor f is also equal to unity. However, if RDS is greater than "0" and the stack exit velocity is less than or equal to the mean wind speed at stack height, f is equal to zero (*i.e.*, the plume rise is set equal to zero). See Equation (2-5) for f values when the stack exit velocity to mean wind speed ratio is between 1.5 and 1.0.

Stack Source Parameter	
TSB	Variable Stack Gas Exit Temperature -- This parameter gives the variable stack gas exit temperature in degrees Kelvin. This parameter only occurs with the parameters NUMSQB and QB. If this parameter is not punched or is set to a value of "0", the program reverts to the constant gas temperature given by TS above. If the user desires to input this parameter, the user must punch 10000 + TS or 10000 plus the gas exit temperature. The value of 10000 is used only as a flag to the program and is removed internally.
VOLB	Variable Volumetric Emission Rate -- This parameter gives the variable stack volumetric emission rate in cubic meters per second. This parameter only occurs with the parameters NUMSQB, QB and TSB. If this parameter is not punched or is set to a value of "0", the program reverts to the constant volumetric emission rate given by VOL above. If the user desires to input this parameter, the user must punch 10000 + VOL or 10000 plus the volumetric emission rate. The value of 10000 is used only as a flag to the program and is removed internally.

Building or Area Source Parameters	
S1	Length of Short Side -- This parameter gives the length in meters of the short side of a building or area source.
S2	Length of Long Side -- This parameter gives the length in meters of the long side of a building or area source. S2 should be less than or equal to two times S1.

Building or Area Source Parameters	
DTH	Angle to Long Side -- This parameter gives the angle, measured clockwise from zero degrees (north), to the long side (S2) of the building or area source in degrees.

3.1.3 Output Information

The SHORTZ program generates four categories of program output. Each category is optional to the user. That is, the user controls all output other than warning and error messages. In the following paragraphs, each category of output is related to the specific input parameter that controls the output category. All program output are printed except for magnetic tape output.

a. Input Parameters Output. The SHORTZ program will print all of the input data except for meteorological data if the parameter ISW(5) is set equal to a value of "3". Only control and general input parameters are printed if ISW(6) = "1" and only source data are printed if ISW(6) = "2". An example of this output is shown in Figure 3-2 of Section 3.2.4 and in the example problem given in Appendix C.

b. Meteorological Parameters Output. The SHORTZ program will print the input meteorological data if the parameter ISW(8) is set to a value of "1". An example of the printed meteorological data is shown in Figure 3-3 of Section 3.2.4 and in the example problem given in Appendix C.

c. Concentration. The parameters (ISW(2) through ISW(5) control the averaging times for which average ground-level concentrations are printed. The program can be directed to print the concentrations calculated at the base input rate using ISW(2). Also, as many as three additional averaging times can be specified for the concentration calculations. For example, if the user sets ISW(1) equal to "1" (indicating hourly input data) and ISW(3) equal to "3", the program will print the 3-hour average concentrations for each 3-hour period in the input meteorological data. Also, by the use of NGROUP the user may print the concentration tables for any desired source or group of sources. Examples of the printed concentration tables are shown in Figures 3-4 through 3-10 of Section 3.2.4 and in the example problem in Appendix C.

e. Magnetic Tape Output. The SHORTZ program will write all input data and all concentration calculations to magnetic tape. These data are written to the logical unit numbers specified by the parameter array NOTFL. This tape must be assigned prior to the execution of the SHORTZ program and the tape(s) must be equated to the logical unit number(s) given in NOTFL. The program saves only the concentrations calculated at the base input meteorological data rate on the output tape. This output tape can be read back into the SHORTZ program to print tables not output in the original run and/or to modify the source inventory for corrections or updates in the source emissions. The instructions on how to assign the output magnetic tape are given in Section 3.2.2 and approximations as to the length of magnetic tape required are given in Section 3.2.5.c. A more detailed description of the contents and format of the output tape file is given in Section 3.2.4.

3.2 USER'S INSTRUCTIONS FOR THE SHORTZ PROGRAM

3.2.1 Program Description

The short-term (SHORTZ) program is designed to calculate average ground-level concentrations produced by emissions from multiple stack, building and area sources. The ground-level concentrations can be calculated for the base input meteorological data rate as well as for as many as three additional averaging times for a maximum of 300 sources. The program is capable of producing concentration tables for each individual source input as well as for user-selected groups of sources. The program concentration calculations are performed for an input set of receptor coordinates defining a fixed receptor grid system and/or for discrete (arbitrarily placed) receptor points. The receptor grid system may be a right-handed Cartesian coordinate system or a polar coordinate system. In either case, zero degrees (north) is defined as the positive Y axis and ninety degrees (east) is defined as the positive X axis and all points are relative to a user-defined hypothetical origin (normally (X=0, Y=0), although the Universal Transverse Mercator (UTM) coordinates may be used as the Cartesian coordinate system).

Capabilities of the SHORTZ program include:

- The capability to calculate 1-hour, 2-hour, 3-hour, etc. average ground-level concentrations
- The capability to process up to 300 sources
- The capability to model stacks, building sources and area sources in the same execution
- The capability to specify source locations anywhere within or outside of the receptor grid system or discrete receptor points
- The capability to display concentrations from individual sources
- The capability to display combined (summed) concentrations from multiple user-defined subsets of the sources or from all sources

- The capability of saving the results of all calculations, the source data and the meteorological data on a master source/concentration inventory magnetic tape

- The capability of updating (adding to, modifying or deleting) a master source/concentration inventory magnetic tape

- The capability to specify a regular receptor array or a set of discrete (arbitrarily placed) points or both

- The capability to specify a right-handed Cartesian coordinate system or a polar coordinate system for the regular receptor array or for the discrete (arbitrarily placed) receptors

- The capability to specify terrain elevations for each receptor and source

- The capability of using 1-hour, 2-hour, 3-hour, etc. average meteorological data

- The capability of specifying site specific meteorological data

- The capability to vary source emissions with each input meteorological observation

The SHORTZ computer program is written in FORTRAN and is designed for use on a UNIVAC 1110 computer. The program requires approximately 55,000 words (UNIVAC 1110) of executable core for instruction and data storage. The program also requires from two to four input/output devices, depending on whether the tape input/output options are used. Input card image data is referenced as logical unit 5 and print output, which requires 132 character print columns, is referenced as logical unit 6. The optional tape input is referenced as logical unit 2 and the output is referenced as logical unit 3. The user has the option of either using the default logical unit numbers given here or specifying alternate logical unit numbers. Also, the SHORTZ program requires random access mass storage referenced as logical unit 12. The mass storage is automatically assigned by the program and is transparent to the user. The computer program consists of a main program SHORTZ and 11 subroutines (MODEL, BLOCKS, OUTPT, TITLR, ACR, ACCM, ZRO, ERFX, INPOUP, ASSIGN and DEFFIL). The FORTRAN source code for each of these routines is given in Appendix A.

3.2.2 Control Language and Data Deck Setup

a. Control Language Requirements. The following illustrates the required ECL control statement runstream for a typical run on a UNIVAC 1110 Operating System:

1.	@RUN,priority jobid,account,userid,time,pages	
2.	@SYM PRINT$,,device	Optional, used to direct print output to a specific print device when running in batch mode.
3.	@ASG,A prog-file.	
4.	@ASG,A data-file.	Optional, used only when the SHORTZ program input data has been placed in a file or data element within a file.
5.	@ASG,options input-tape-file.,type,reel-number @USE nn,input-tape-file.	Optional, required only if KSW=1 or 3.
	@MOVE input-tape-file.,ℓ	Optional, required only if the input-tape-file is file ℓ+1 on tape, ℓ>1.

```
                                                         (Optional, required
6.   @ASG,options  output-tape-file.,type,reel-number    )only if KSW=2 or 3
                                                         )and data are output
     @USE mm,output-tape-file.                           (to tape.

                                                         (Optional, required only
     @MOVE  output-tape-file.,ℓ                          )if the output-tape-file
                                                         )is file ℓ+1 on tape,
                                                         (ℓ>1.

                                                         (Optional, used to di-
7.   @ASG,CP  print-file.                                )rect print output to a
     @BRKPT  PRINT$/print-file                           <specific print device
                                                         )when running in demand
                                                         (mode.

8.   @XQT  prog-file.SHORTZ

                                                         (Input data cards for the
9.   card-input-data                                     <SHORTZ program when pro-
                                                         (gram is run in batch mode.

          or

                                                         (SHORTZ input data cards
     @ADD  data-file.                                    <have been placed in a
                                                         (data file.

          or

                                                         (SHORTZ input data cards
     @ADD  data-file.data-name                           )have been placed in a
                                                         )symbolic element in a
                                                         (data file.

10.  @BRKPT  PRINT$                                      (Optional, used with 7
     @FREE  print-file.                                  )above to direct the
     @SYM  print-file,,device                            )print output to a speci-
                                                         (fic print device.

11.  @FIN

     where
```

priority = job run priority

jobid = six-character user supplied job identification or terminal site identification name.

account = account number

userid = 12-character user supplied project number or user number.

time = execution time required in minutes

pages = output pages required

device = printer symbiont name, onsite or remote, to which you desire the print file to go.

prog-file = the name of the program file. This illustration assumes the user (installation) has assembled and collected (linked) the short-term program into this file and called the absolute program SHORTZ.

data-file = the name of an optional data file into which the user has placed the input card data for SHORTZ.

input-tape-file = a user supplied file name used to reference the optional source/concentration inventory input tape. This tape was created by a previous run of the SHORTZ program.

options = tape assignment options T,H,F,J,/W

T - temporary, tape

H - high density, use only if U9H is specified for type.

F - tape file is to be labeled with a label that requires only the reel-number to be correct. Use this option only on output permanent tapes that are to be labeled.

J - specifies the tape is unlabeled. This option may not be allowed at your installation for permanent tapes. However, the J option should be specified for scratch tapes.

/W - specifies the tape is an output tape and a write ring is to be inserted.

The options follow the comma and are placed together in a continuous string.

type = the type of tape input/output device. Use 16N or U9V if the tape density is 1600 bpi or use U9H if the tape density is 800 bpi.

reel-number = the physical tape reel-number assigned by the installation tape librarian. Each tape reel-number is unique. If a scratch tape is desired for an output, then type BLANK for reel-number.

nn = the FORTRAN logical unit number with which the SHORTZ program is to reference (read) the input tape. This number is defined under the NINFL parameter input option. This number cannot equal any of the standard I/O (card reader, printer, punch) device logical unit numbers and must be a value allowed by the UNIVAC NTRAN I/O routines at your installation. The default input unit number for SHORTZ is "2".

ℓ = the number of file-marks to space over on the input tape to position the tape at the desired input data set. The MOVE card is only required if $\ell > 1$.

output-tape-file = a user supplied file name used to reference the optional source/concentration inventory output tape. This tape must be assigned using the W option.

mm = the FORTRAN logical unit number with which the SHORTZ program is to reference (write) the output tape. This number is defined under the NOTFL parameter input option. This number cannot equal any of the standard I/O (card reader, printer, punch) device logical unit numbers and must be a value allowed by the UNIVAC NTRAN I/O routines at your installation. The default output unit number for SHORTZ is "3".

print-file = optional, user supplied, file name to be used for the SHORTZ print output file. If the user is running from an interactive terminal and this option is not used, all printout will be printed at the terminal in 132 character line images. As the print output volume could be large, it is recommended that the print-file option be used and the print file be SYM'ed to an on-site printer (in 10.) after the execution of SHORTZ.

card-input-data = SHORTZ program input card data defined in Section 3.1.2 and shown in Figure 3-1. If the user is running from an interactive terminal, it is recommended that the data be placed in a data file or in a symbolic element within a data file prior to execution of SHORTZ. The user would then use an @ADD command to add the data to the run-stream.

b. Data Deck Setup. The card input data required by the SHORTZ program depends on the program options desired by the user. The card input deck may be partitioned into six major groups of card data. Figure 3-1 illustrates the input deck setup. The six major input deck groups are:

1. Title Card (One data card always included in the input deck).

2. Program Option and Control Cards (Three data cards always included in the input deck. However, not all parameters on these cards are used when tape input is used).

3. Receptor Data Cards (The number of data cards included in this group depends on the parameters NXPNTS, NYPNTS, NXWYPT and ISW(7). These cards are not included in the input deck if tape input is used, KSW = "1" or "3").

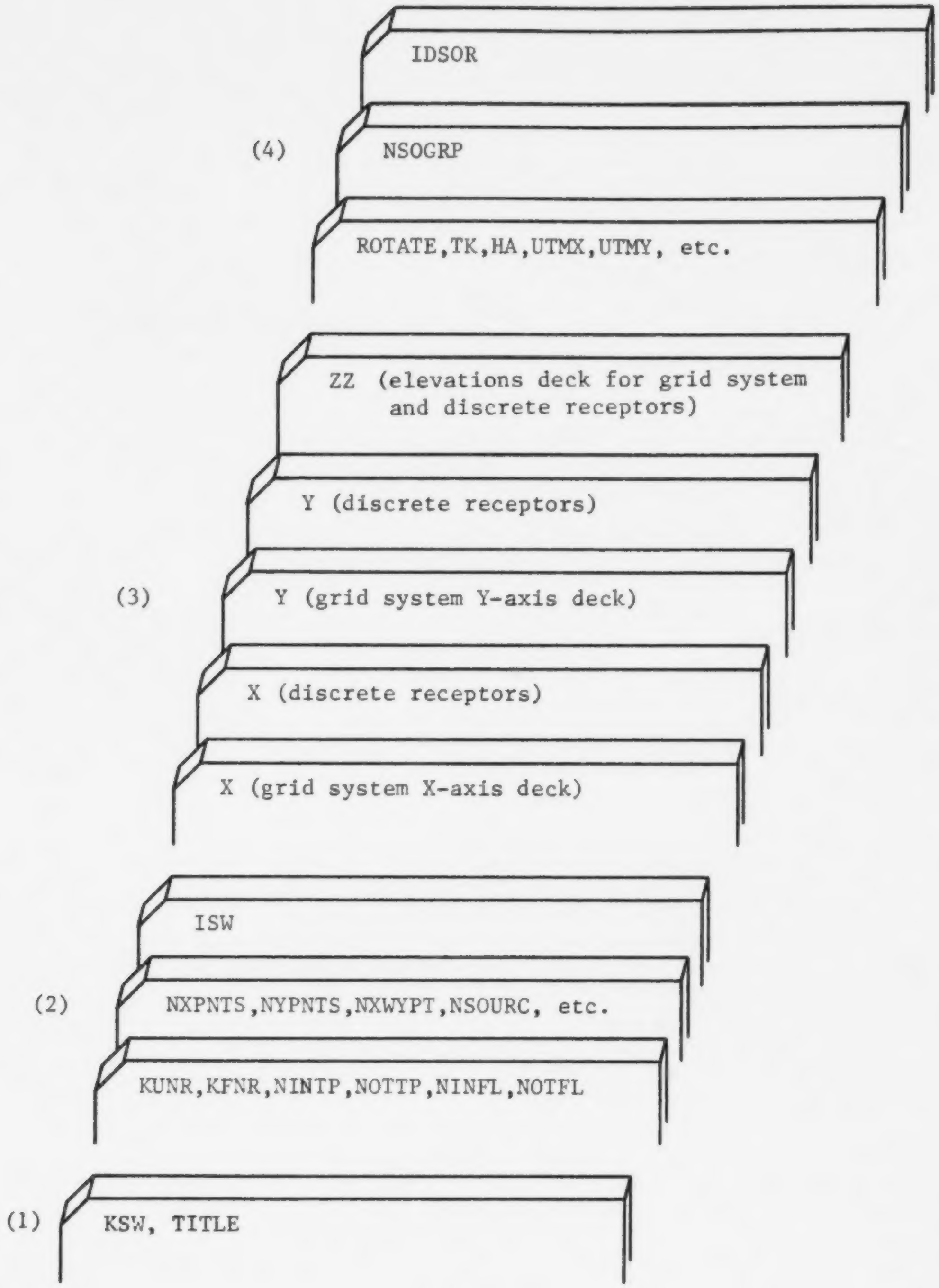

IDSOR
(4)
NSOGRP
ROTATE,TK,HA,UTMX,UTMY, etc.
ZZ (elevations deck for grid system and discrete receptors)
Y (discrete receptors)
(3)
Y (grid system Y-axis deck)
X (discrete receptors)
X (grid system X-axis deck)
ISW
(2)
NXPNTS,NYPNTS,NXWYPT,NSOURC, etc.
KUNR,KFNR,NINTP,NOTTP,NINFL,NOTFL
(1)
KSW, TITLE

FIGURE 3-1. Input data deck setup for the SHORTZ program.

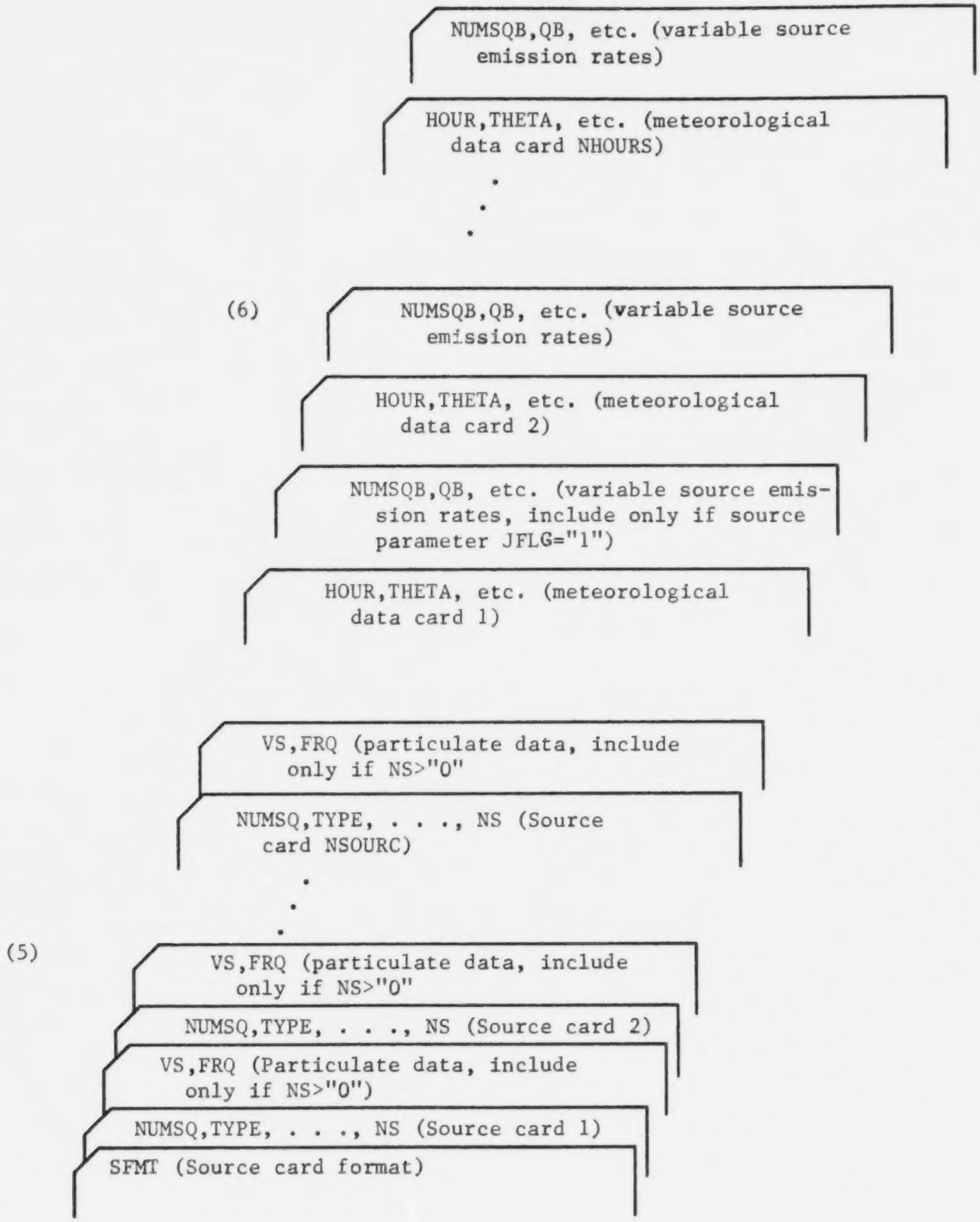

NUMSQB,QB, etc. (variable source emission rates)
HOUR,THETA, etc. (meteorological data card NHOURS)
(6)
NUMSQB,QB, etc. (variable source emission rates)
HOUR,THETA, etc. (meteorological data card 2)
NUMSQB,QB, etc. (variable source emission rates, include only if source parameter JFLG="1")
HOUR,THETA, etc. (meteorological data card 1)
VS,FRQ (particulate data, include only if NS>"0"
NUMSQ,TYPE, . . ., NS (Source card NSOURC)
(5)
VS,FRQ (particulate data, include only if NS>"0"
NUMSQ,TYPE, . . ., NS (Source card 2)
VS,FRQ (Particulate data, include only if NS>"0")
NUMSQ,TYPE, . . ., NS (Source card 1)
SFMT (Source card format)

FIGURE 3-1. (Continued)

4. Model and Source Concentration Control Cards (The first card of this group is included in the input deck only if tape input is not being used. The remaining cards are included only if NGROUP > "0").

5. Source Data Cards (This card group is included in the input deck only if NSOURC > "0". Also, the first card in this group is included in the deck only if ISW(12) = "1". The particulate data cards follow each source card only if the parameter NS on the source card is greater than "0").

6. Meteorological Data Cards (This card group is included in the input deck only if tape input is not being used. Also, the program will expect NDAYS sets of these data in the input deck. The variable source emission rate cards are included in the deck only if one or more of the source cards in (5) had the parameter JFLG = "1").

3.2.3 Input Data Description

Section 3.1.2 provides a summary description of all input data parameter requirements for the SHORTZ program. This section provides the user with the FORTRAN format and order in which the program requires the input data parameters. The input parameter names used in this section are the same as those introduced in Section 3.1.2. Two forms of input data may be input to the program. One form is card image input data (80 characters per record) in which all required input data may be entered. The other form is magnetic tape on which some of the required data were stored as part of a previous run of the SHORTZ program. Both forms of input are discussed below.

a. Card Input Requirements. The SHORTZ program reads all card image input data in a fixed-field format with the use of a FORTRAN

"A", "I" or "F" editing code (format). Each parameter value must be punched in a fixed-field on the data card defined by the start and end card columns specified for the variable. Table 3-5 identifies each variable by name and respective card group. Also, Table 3-5 specifies the card columns (fixed-field) for the parameter value and the editing code ("A", "I" or "F") used to interpret the parameter value. Parameters using an "A" editing code are alpha-numeric data items used primarily for labeling purposes. These data items can be punched anywhere in the specified data columns and can consist of any character information. If not punched, these data items are interpreted as blanks. Parameters using an "I" editing code are integer (whole number) data items. These data items must be numeric punches only and must be punched (right justified) so the units digit of the number is in the right most column of the field. If the punch field for the variable is not punched (left blank), it is interpreted as zero. Parameters using an "F" editing code are real number data items. These data items can be punched like integer ("I") data items (right justified) if they are whole numbers. However, they must be punched with a decimal point (".") if they contain a fractional part.

Card Group 1 in Table 3-5 gives the print output page heading and is always included in the input data deck. Any information to identify the output listing or data case may be punched into this card. If the card is left blank, the heading will consist of only the output page number unless an input tape is being used.

Card Group 1a contains the label parameters that specify the concentration print output units (KUNR), the source emission rate input units (KFNR) and the parameters that specify the number of input and output tapes and their respective logical unit numbers (NINTP, NOTTP, NINFL, NOTFL). This card group is always read by the program and, if an input tape is being used (ISW = "1" or "3"), the arrays KUNR and KFNR, if blank, are taken from the input tape.

TABLE 3-5

SHORTZ PROGRAM CARD INPUT PARAMETERS
FORMAT AND DESCRIPTION

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
1	KSW	1	I1	Optional input/output master source/concentration inventory tape Blank or 0 = no input/output tape 1 = input tape is read from the unit(s) specified in NINFL below. 2 = output tape is written to the unit(s) specified in NOTFL below. 3 = both input and output tapes are to be used.
	TITLE	2-80	19A4,A3	79 character page heading label
1a	KUNR	1-24	6A4	24 characters giving the concentration print output units. This label is automatically filled if the parameter TK on Card Group 6 is defaulted. If this label is punched, start in column 1 and include leading and ending parentheses.
	KFNR	25-36	3A4	12 characters giving the source emission rate input units. This label is automatically filled if the parameter TK on Card Group 6 is defaulted. If this label is punched, start in column 25 and include leading and ending parentheses.
	NINTP	37-40	I4	Blank or 0 = program assumes a maximum of one input tape 3 ≥ n > 0 = number of input tapes

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
la (Cont.)	NOTTP	41-44	I4	Blank or 0 = program assumes a maximum of one output tape $3 \geq n > 0$ = number of output tapes
	NINFL (1)	45-48	I4	Blank or 0 = program assumes the first input tape is logical unit 2 $n > 0$ = logical unit number used to reference the first input tape
	NINFL (2)	49-52	I4	Blank or 0 = program assumes there is no more than one input tape $n > 0$ = logical unit number used to reference the second input tape
	NINFL (3)	53-56	I4	Blank or 0 = program assumes there are no more than two input tapes $n > 0$ = logical unit number used to reference the third input tape
	NOTFL (1)	57-60	I4	Blank or 0 = program assumes the first output tape is logical unit 3 $n > 0$ = logical unit number used to reference the first output tape
	NOTFL (2)	61-64	I4	Blank or 0 = program assumes there is no more than one output tape $n > 0$ = logical unit numbers used to reference the second output tape
	NOTFL (3)	65-68	I4	Blank or 0 = program assumes there are no more than two output tapes $n > 0$ = logical unit number used to reference the third output tape

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
2	NXPNTS*	1-4	I4	Number of receptors in the X axis of the receptor grid system
	NYPNTS*	5-8	I4	Number of receptors in the Y axis of the receptor grid system.
	NXWYPT*	9-12	I4	Number of discrete (arbitrarily placed) receptor points
	NSOURC	13-16	I4	Number of card image input sources to be read under Card Groups 9a through 10 below
	NHOURS*	17-20	I4	Total number of meteorological observations the program is to process. Card Group 11 is read NHOURS times by the program for each case, 1 to NDAYS (default = 24)
	NGROUP	21-24	I4	Number of different source combinations used to print concentration (maximum = 1000). A source combination consists of one or more sources
	NDAYS*	25-28	I4	Number of days or cases of meteorological data to process (default = 1)

*These parameters are set automatically by the program and cannot be changed if tape input (KSW = 1 or 3) is being used.

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
3	ISW(1)*	1-4	I4	Blank, 0 or 1 = each meteorological observation is one hour n > 1 = each meteorological input card represents one n-hour observation
	ISW(2)	5-8	I4	Blank or 0 = concentration calculated at the base meteorological input data rate are not printed 1 = concentrations calculated at the base meteorological input data rate are printed
	ISW(3)	9-12	I4	Blank or 0 = do not print average concentration using this option n > ISW(1) = calculate and print n-hour average concentration for each successive n-hour period
	ISW(4)	13-16	I4	Blank or 0 = do not print average concentration using this option n > ISW(3) = calculate and print n-hour average concentration for each successive n-hour period

*These parameters are set automatically by the program and cannot be changed if tape input (KSW = 1 or 3) is being used.

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
3 (Cont.)	ISW(5)	17-20	I4	Blank or 0 = do not print average concentration using this option n > ISW(4) = calculate and print n-hour average concentration for each successive n-hour period
	ISW(6)	21-24	I4	Blank or 0 = do not print control or source input data 1 = print input control data only 2 = print input source data only 3 = print both input control and source data
	ISW(7)*	25-28	I4	Blank or 0 = do not read terrain elevation data (ZZ) from Card Groups 5B and 5C 1 = terrain elevation data are to be read from Card Groups 5B and/or 5C
	ISW(8)	29-32	I4	Blank or 0 = do not print the input meteorological data 1 = print the input meteorological data

*These parameters are set automatically by the program and cannot be changed if tape input (KSW = 1 or 3) is being used.

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
3 (Cont.)	ISW(9)*	33-36	I4	Blank or 0 = wind speed power law is based on the emission elevation above airport or weather station elevation. If the emission elevation is below the weather station, no power law is used 1 = wind speed power law is based on the emission height above the terrain and a power law is always used
	ISW(10)	37-40	I4	Blank or 0 = all print output is printed on logical unit 6 n > 0 = all print output is written to logical unit n. If n is not equal to 6 or 56, two end of file marks are written on the output unit and it is rewound at the completion of the program
	ISW(11)*	41-44	I4	Blank or 0 = do not average concentration over days or cases (NDAYS) 1 = concentration for each n-hour period selected (ISW(2) through ISW(5)) is averaged over NDAYS

*These parameters are set automatically by the program and cannot be changed if tape input (KSW = 1 or 3) is being used.

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
3 (Cont.)	ISW(12)	45-48	I4	Blank or 0 = do not read the format for source data (Card Group 9), but use the default format 1 = the format for the card source data (SFMT, Card Group 9) is read by the program
	ISW(13)*	49-52	I4	Blank or 0 = receptor grid system is in rectangular Cartesian coordinates 1 = receptor grid system is in polar coordinates relative to the point specified by UTMX and UTMY
	ISW(14)*	53-56	I4	Blank or 0 = discrete (arbitrarily placed) receptors are in rectangular Cartesian coordinates 1 = discrete receptors are in polar coordinates relative to the point specified by UTMX and UTMY

*These parameters are set automatically by the program and cannot be changed if tape input (KSW = 1 or 3) is being used.

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
3 (Cont.)	ISW(15)*	57-60	I4	Blank or 0 = source locations are in rectangular Cartesian coordinates 1 = source locations are in polar coordinates relative to the point specified by UTMX & UTMY
	ISW(16)*	61-64	I4	Blank or 0 = the same turbulent intensities (SIGEPU, SIGAPU) are used for all source types 1 = different turbulent intensities are to be entered for stacks and for area and building sources. Use SIGEPU and SIGAPU for stack (TYPE=0) sources and SIGEPL and SIGAPL for building (TYPE=1) and area (TYPE=2) sources. No default turbulent intensities are provided for this option.
	ISW(17)*	65-68	I4	Blank or 0 = default turbulent intensities are Cramer, et al. (1975) rural values if ISW(16)=0. The program will not use default turbulent intensities if ISW(16)=1. 1 = default turbulent intensities are Cramer, et al. (1975) urban values if ISW(16)=0. The program will not use default turbulent intensities if ISW(16)=1.

*These parameters are set automatically by the program and cannot be changed if tape input (KSW = 1 or 3) is being used.

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
3 (Cont.)	ISW(18)*	69-72	I4	Reserved for future options
	ISW(19)*	73-76	I4	Reserved for future options
	ISW(20)*	77-80	I4	Reserved for future options
4**	X	1-10 11-20 : 71-80 (for each card)	8F10.0	Array of NXPNTS receptor points in meters in ascending order defining the X axis of the receptor grid system. If only the first two points are non-zero, the program assumes the first is the start of the axis and the second is the increment it uses to generate the remaining points. This card group is omitted from the input data deck if NXPNTS = 0
4a**	X (discrete)	1-10 51-20 : 71-80 (for each card)	8F10.0	Array of NXWYPT discrete receptor points in meters. This card group is omitted from the input data deck if NXWYPT = 0
5**	Y	1-10 11-20 : 71-80 (for each card)	8F10.0	Array of NYPNTS receptor points in meters or degrees depending on ISW(13) in ascending order defining the Y axis of the receptor grid system. If only the first two points are non-zero, the program assumes the first is the start of the axis and the second is the increment used to generate the remaining points. This card group is omitted from the input data deck if NYPNTS = 0

*These parameters are set automatically by the program and cannot be changed if tape input (KSW = 1 or 3) is being used.

**These card groups are omitted from the input card deck if tape input (KSW = 1 or 3) is being used. The information for these parameters is taken from the input tape.

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
5a**	Y (discrete)	1-10 11-20 : 71-80 (for each card)	8F10.0	Array of NXWYPT discrete receptor points in meters or degrees depending on ISW(14). This card group is omitted from the input data deck if NXWYPT = 0
5b**	ZZ	1-10 11-20 : 71-80 (for each card)	8F10.0	Array of terrain elevations in meters for each receptor of the NXPNTS by NYPNTS grid system. This card group is omitted from the input data deck if either ISW(7) = 0 or an input tape is being used. See the text for the order of values input to this card group.
5c**	ZZ (discrete)	1-10 11-20 : 71-80 (for each card)	8F10.0	Array of terrain elevations in meters for each discrete receptor. This card group is omitted from the input card deck if ISW(7) = 0 or NXWYPT = 0.
6**	ROTATE	1-7	F7.0	Wind direction correction parameter used to correct for any difference in north as defined by the reference receptor grid system and north as defined by the weather station at which the weather data were recorded. The value of ROTATE is subtracted from each wind direction category

**These card groups are omitted from the input card deck if tape input (KSW = 1 or 3) is being used. The information for these parameters is taken from the input tape.

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
6** (Cont.)	TK	8-17	F10.0	Model units conversion factor used to produce the desired output concentration units from the input source emission rate units. The concentration default for TK is 1×10^6 micrograms per gram assuming output in micrograms per cubic meter and input source units in grams per second. If the default is chosen, the parameters KUNR and KFNR above on Card Group la are automatically set
	HA	18-24	F7.0	Elevation in meters (MSL) of the airport or weather station at which the meteorological data were recorded. The default value is zero
	UTMX	25-31	F7.0	East-west Cartesian (UTM) coordinate in meters of the origin for polar coordinates. The default value is zero
	UTMY	32-38	F7.0	North-south Cartesian (UTM) coordinate in meters of the origin for polar coordinates. The default is zero.
	G	39-45	F7.0	Acceleration due to gravity in meters per second squared. The default is 9.8 m/sec^2

**These card groups are omitted from the input card deck if tape input (KSW = 1 or 3) is being used. The information for these parameters is taken from the input tape.

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
6** (Cont.)	ZR	46-52	F7.0	Height in meters above ground at airport or weather station at which the wind speed is measured. The default value is 6.096 meters.
	GAMMA1	53-57	F5.0	Air entrainment coefficient for an adiabatic or unstable atmosphere. The default is 0.6 (Briggs, 1972)
	GAMMA2	58-62	F5.0	Air entrainment coefficient for a stable atmosphere. The default is 0.66 (Briggs, 1972).
	DECAY	63-73	F11.0	Coefficient (seconds^{-1}) of time dependent pollutant removal by physical or chemical processes. Default is zero or no decay.
	XRY	74-80	F7.0	Distance over which rectilinear expansion occurs downwind from an ideal point source in meters. The default is 50 meters

**These card groups are omitted from the input card deck if tape input (KSW = 1 or 3) is being used. The information for these parameters is taken from the input tape.

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
7	NSOGRP	1-4 5-8 : 77-80	20I4	Array used to specify the number of source ID-numbers you are using to define each source combination. There are NGROUP values read here. This data card is omitted from the input card deck if NGROUP = 0. There are a maximum of 1000 values that can be input here
8	IDSOR	1-6 7-12 : 73-78 (for each card)	13I6	Array used to specify the source ID-numbers to use in forming the combined source output and individual source output. There are a maximum of 1000 values that can be input here. This data card group is omitted from the input card deck if NGROUP = 0
9**	SFMT	1-80	20A4	Array specifying the format used to read Card Group 9a (not read if ISW(12) = 0). Default format is (I5, 3I1, F10.0, 8F7.0, I2)
9a**	NUMSQ	1-5	I5	Source identification number. Input all sources in ascending order of the identification number. Card Groups 9a through 10 are omitted from the input data deck if NSOURC equals zero. Remember to group Card Groups 9a and 10 together as a set for each input source

**These card groups are omitted from the input card deck if the parameter NSOURC is equal to "0".

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
9a** (Cont.)	TYPE	6	I1	Source type. Blank or 0 = stack 1 = building 2 = area
	DISP	7	I1	Source disposition. Blank or 0 = new input source or replace old tape source if it has same ID-number. Next card group read is 10 if NS > 0, otherwise it is Card Group 9a. 1 = use source emission rates on this card to rescale or re-calculate concentrations for source NUMSQ. Next card group read is 9a 2 = delete incoming tape source and concentration for source NUMSQ. Next card group read is 9a
	JFLG	8	I1	Blank or 0 = source emission rate for this source is constant and is given by Q

**These card groups are omitted from the input card deck if the parameter NSOURC is equal to "0".

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
9a** (Cont.)	JFLG (Cont.)	8	I1	1 = source emission rate varies with each meteorological data input observation and is read by the program in QB, Card Group 11a
	Q	9-18	F10.0	Constant source emission rate in units of mass per unit time. The default value is "0" and the default units are grams per second
	DX	19-25	F7.0	Cartesian X coordinate of the source in meters or the range in polar coordinates in meters depending on ISW(15)
	DY	26-32	F7.0	Cartesian Y coordinate of the source in meters or the azimuth bearing in polar coordinates in degrees depending on ISW(15)
	H	33-39	F7.0	Height above the ground of the emission in meters
	HS	40-46	F7.0	Elevation in meters above mean sea level at the source location
	TS or S1	47-53	F7.0	This field depends on the source type -- if TYPE = 0, TS = stack gas exit temperature in degrees Kelvin

**These card groups are omitted from the input card deck if the parameter NSOURC is equal to "0".

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
9a** (Cont.)	TS or S1 (Cont.)	47-53	F7.0	TYPE = 1 or 2, S1 = length of the short side of the building or area source in meters
	VOL or S2	54-60	F7.0	This field depends on the source type -- if TYPE = 0, VOL = stack gas volumetric emission rate (m^3/sec) TYPE = 1 or 2, S2 = length of the long side of the building or area source in meters
	DTH	61-67	F7.0	Angle in degrees clockwise from zero degrees (north) to long side of volume or area source
	RDS	68-74	F7.0	Inner stack radius in meters used to limit plume rise for the wake effects of stacks or buildings. See the text for the proper value to input here
	NS	75-76	I2	Number of particulate size categories in the particulate distribution for concentration with depletion due to dry deposition. The maximum value of this parameter is 20. If terrain elevations are being used this parameter must be omitted or must equal zero

**These card groups are omitted from the input card deck if the parameter NSOURC is equal to "0".

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
10	VS	1-10 11-20 ⋮ 71-80 (for each card)	8F10.0	Array of settling velocities in meters per second for each particulate size category. This card group is omitted from the input data deck if NS = 0 on Card Group 9a.
	FRQ	These values immediately follow the last value of VS on the data card(s)	8F10.0	Array of mass fraction of the particulate distribution for each category. The sum of the fractions in this array should total 1 (100% of the distribution). This card group is omitted from the input data deck if NS = 0
11**	HOUR	1-4	I4	Hour of the meteorological observation (00 - 23 or 0000 - 2300)
	THETA	5-11	F7.0	Direction in degrees from which the wind is blowing. No default is provided
	UBAR	12-19	F8.0	Wind speed in meters per second. No default is provided

**These card groups are omitted from the input card deck if tape input (KSW = 1 or 3) is being used. The information for these parameters is taken from the input tape.

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
11**	HM	20-28	F9.0	Surface mixing layer depth in meters. No default is provided
	TA	29-35	F7.0	Ambient air temperature in degrees Kelvin. No default is provided
	DPDZ	36-40	F5.0	Vertical gradient of potential temperature in degrees Kelvin per meter. No default is provided
	ISTBLE	41	A1	Pasquill stability categories (A, B, C, D, E or F) used only to provide default values for SIGEPU, SIGAPU and P if ISW(16)=0
	P	42-45	F4.0	Wind profile power law exponent. Default values depend on the wind speed and stability category given by ISTBLE and are shown in Table 3-4
	SIGEPU	46-53	F8.0	Standard deviation of the wind elevation angle in degrees ($\geq$ 1.0) or radians (< 1.0) for all sources, if ISW(16)=0 or stack (TYPE=0) sources only, if ISW(16)=1. Default values are provided only if ISW (16)=0. Default values depend on the stability category given by ISTBLE and are shown in Table 3-4. Also, default values depend on ISW(17) (rural/urban mode)

**These card groups are omitted from the input card deck if tape input (KSW = 1 or 3) is being used. The information for these parameters is taken from the input tape.

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
11** (Cont.)	SIGAPU	54-61	F8.0	Standard deviation of the wind direction angle in degrees (≥ 1.0) or radians (< 1.0) for all sources, if ISW(16) ="0" or stack (Type=0) sources only, if ISW(16)="1". Default values are provided only if ISW(16)= "0". Default values depend on the stability category given by ISTBLE and are shown in Table 3-4. Also, default values depend on ISW(17) (rural/urban mode).
	SIGEPL	62-69	F8.0	Standard deviation of the wind elevation angle in degrees (≥ 1.0) or radians (< 1.0) for building and area sources if ISW (16)="1". No default values are provided.
	SIGAPL	70-77	F8.0	Standard deviation of the wind direction angle in degrees (≥ 1.0) or radians (< 1.0) for building and area sources if ISW(16)= "1". No default values are provided.
	ALPHA	78-80	F3.0	Lateral diffusion coefficient. The default value is 0.9
11a**	NUMSQB	1-6	I6	Source identification number of a source with the parameter JFLG equal to 1 on Card Group 9a. Each source in Card Group 9a that has JFLG set to 1 must

**These card groups are omitted from the input card deck if tape input (KSW = 1 or 3) is being used. The information for these parameters is taken from the input tape.

TABLE 3-5 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
11a** (Cont.)	NUMSQB (Cont.)	1-6	I6	have one Card Group 11a following each occurrence of Card Group 11 in the input deck
	QB	7-16	F10.0	Emission rate for the source given by NUMSQB and for the hour given by HOUR on Card Group 11. The units are mass per unit time with default units of grams per second. The default value of QB is 0
	TSB	17-26	F10.0	Blank or 0 = ignored by the program n = TS + 10000 = stack gas exit temperature in degrees Kelvin plus 10000 for source NUMSQB and hour HOUR
	VOLB	27-36	F10.0	Blank or 0 = ignored by the program n = VOL + 10000 = stack volumetric emission rate in cubic meters per second plus 10000 for source NUMSQB and hour HOUR

**These card groups are omitted from the input card deck if tape input (KSW = 1 or 3) is being used. The information for these parameters is taken from the input tape.

Card Group 2 contains those parameters that specify the size of the receptor arrays, the number of sources, number of observations of meteorological data and the number of days or cases of meteorological data. The parameters NXPNTS, NYPNTS and NXWYPT specify the number of receptor points in the grid system X-axis, Y-axis and the number of discrete receptors, respectively. The size of these parameters are limited by the equation

$$E \geq \text{NXPNTS+NYPNTS+2*NXWYPT+6*(NXPNTS*NYPNTS+NXWYPT)} \qquad (3\text{-}2)$$

where the value of E equals 12000. The value of E can be increased to a maximum value of 64000 by changing MMM in the parameter statement on line number 24 (sequence number S0100230)

```
PARAMETER MMM = 12000
```

of the program listing of the main short-term model, SHORTZ, in Appendix A. The parameter NSOURC specifies the number of card input sources. The maximum number of sources the program can process from both card and tape is 300. However, this value can be increased to a maximum of 1000 by changing MKQ in the parameter statement on line number 12 (sequence number S0100110)

```
PARAMETER MKQ = 300
```

in the program listing of the main SHORTZ and in subroutines BLOCKS at line number 3 (sequence number S0200020), MODEL at line number 12 (sequence number S0300110) and OUTPT at line number 9 (sequence number S0400080) in Appendix A. The parameter NHOURS specifies the total number of input meterological observations and has a maximum value of 8784. NGROUP specifies the total number of individual and/or combined source output groupings. The program will print the concentration for each specified source combination and each specified concentration averaging time (ISW(2) through ISW(5)). If this parameter is input as zero or not punched, the program assumes all sources are to be used in a single source combination. The last parameter on this card group (NDAYS) specifies the number of days or cases of meteorological data to read and processed. This parameter is used to process multiple sets of disjoint meteorological data or can be used to calculate the N-hour averages of specified meteorological periods (0000-0200, 0300-0500, etc.) averaged over NDAYS days or cases.

Card Group 3 gives the values of the program option array. This card group is always included in the input data deck. However, the values of ISW(1), ISW(7), ISW(9), ISW(11) and ISW(13) through ISW(20) are automatically set by the program if you are using an input (source/concentration inventory) tape. The options on this card that determine whether or not certain card groups are included in the deck are ISW(7) and ISW(12). If ISW(7) is left blank or punched zero, Card Groups 5b and 5c are omitted from the input data deck. Also, if ISW(12) is left blank or punched zero, Card Group 9 is omitted from the input data deck.

Card Group 4 through 5c specify the X, Y and Z coordinates of all receptor points. Card Groups 4, 5 and 5b are omitted from the input card deck if the parameters NXPNTS and NYPNTS equal zero or if an input tape is being used. Also, Card Groups 5b and 5c are omitted if ISW(7) equals "0" or no terrain elevations are being used. Card Groups 4a, 5a and 5c are also omitted from the input card deck if the parameter NXWYPT is zero or if an input tape is being used. Each of these card groups uses a 10 column field for each receptor value and 8 values per data card. The number of data cards required for each card group is defined by the values of the parameters NXPNTS, NYPNTS and NXWYPT. Values input on Card Groups 4 and 5 are always in ascending order (west to east, south to north, 0 to 360 degrees). The terrain elevations for the grid system on Card Group 5b begin in the southwest corner of the grid system or at 0 degrees for polar coordinates. The first data card(s) contain the elevations for each receptor on the X axis (1 to NXPNTS) for the first Y receptor coordinate. A new data card is started for the elevations for each successive Y receptor coordinate. A total of NYPNTS groups of data cards containing NXPNTS values each is required for Card Group 5b. The elevations for the discrete receptors in Card Group 5c are punched across the card for as many cards as required to satisfy NXWYPT elevation values.

Card Group 6 contains meteorological and model constants; a detailed description of these parameters (ROTATE, TK, HA, UTMX, UTMY, G, ZR, GAMMA1, GAMMA2, DECAY AND XRY) is given in Section 3.1.2 above.

Card Groups 7 and 8 always occur together and are included in the input card deck only if NGROUP is greater than zero. Card Group 7 is the array NSOGRP used to specify the number of ID-numbers used to define each source combination. Each value in NSOGRP specifies the number of source ID-numbers to be read from Card Group 8 (IDSOR) in consecutive order for each source combination. A positive source ID-number punched into the array IDSOR indicates to include that source in the combination. A negative source ID-number indicates to include that source as well as all source ID-numbers less in absolute value, up to and including the previous positive source ID-number punched, if it is part of the same group of ID-numbers defining a combination. If the negative value is the first ID-number of a group of ID-numbers, it as well as all sources less in absolute value of ID-number are included in the source combination. See the example given under NSOGRP and IDSOR in Section 3.1.2 and the example problem in Appendix C. The data values are read from Card Group 7 using 4 card columns per value with a maximum of 1000 values and from Card Group 8 using 6 card columns per value, 13 values per card with a maximum of 1000 values.

Card Group 9 is included in the input data deck only if the option ISW(12) equals "1" and only if NSOURC is greater than "0". This card group gives an optional data format for the source data read in Card Group 9a. This optional format, if input, must include the leading and ending parentheses. The default format used, if Card Group 9 is omitted, to read the source parameters on Card Group 9a is (I5, 3I1, F10.0, 8F7.0, I2).

Card Groups 9a and 10 are included in the input data deck only if NSOURC is greater than "0". Card Group 9a consists of the source parameters: NUMSQ, TYPE, DISP, JFLG, Q, DX, DY, H, HS, TS or S1, VOL or S2, DTH, RDS and NS. The parameter NUMSQ on this card must always be punched greater than zero and less than or equal to 20000 in value. This source identification number determines the order of input of each source card, as these cards must be input in ascending order of NUMSQ. However, the consecutive values of NUMSQ do not have to be continuous. Card Group 10 is included in the input deck only if the preceding source card (Card Group 9a) has a value of NS greater than zero. This card group gives the particulate settling velocity (VS) and mass fraction of particulates (FRQ) for each particulate size category. The program reads NS values of VS and FRQ, with the values of FRQ immediately following those of VS on the same data card. The order of these cards is illustrated in Figure 3-1 in Section 3.2.2.b.

Card Group 11 gives each meteorological data observation and Card Group 11a gives the optional variable source emission rates for those sources in Card Group 9a with the variable emission rate option JFLG set equal to "1". These card groups are omitted from the input data deck if tape input (KSW = "1" or "3") is being used. If tape input is not being used, the program expects to read these card groups NHOURS times for each day or case, 1 to NDAYS. The SHORTZ program assumes each occurrence of Card Group 11 is representative of the meteorological conditions over the number of hours in the observation period (averaging time) specified by ISW(1) on Card Group 3. The representative hour of the meteorological data is given by HOUR (00-23 or 0000-2300). The meteorological parameters THETA, UBAR, HM, TA and DPDZ are site-specific parameters and have no default values. The program will provide default values for the parameter P if the Pasquill stability category (ISTBLE) is specified and also for the parameters SIGEPU, SIGAPU, SIGEPL and SIGAPL if the stability category is specified and ISW(16) is equal to "0". However, site specific values for these parameters are recommended. Card Group 11a is read immediately after each occurrence of Card Group 11 only if one or more of the Card Group 9a source data cards has the parameter JFLG equal to "1". For example, if seven of the sources have variable emission rates, the parameter JFLG on those source cards is set equal to "1". The user would then include seven variable emission rate data cards (Card Group 11a) immediately after each occurrence of Card Group 11 in the data deck. The order of these card groups in the data deck is illustrated in Figure 3-1 in Section 3.2.2.b.

b. Tape Input Requirements. The SHORTZ program accepts an input source/concentration inventory tape previously created by the SHORTZ program. This tape, a binary tape written using the UNIVAC 1110 FORTRAN NTRAN I/O routines, was created as an output tape on a previous run of the program. This tape contains all of the program options that affect how the model concentration calculations were performed, all of the receptor and elevation data, all of the meteorological data, all of the source input data and the results of the concentrations calculated at the base input meteorological data rate at each receptor point. The program reads the data from the FORTRAN logical unit number(s) specified by NINFL. The tape data are read only if option KSW equals "1" or "3". *The input tape requires the user to omit specified data card groups from the input deck and makes the input of some parameter values unnecessary.* The omitted Card Groups and unnecessary parameters are indicated by a

* or ** in the Card Group and Parameter Name columns of Table 3-5. The format and exact contents of the input tape are discussed in Section 3.2.4.b below.

3.2.4 Program Output Data Description

The SHORTZ program generates several categories of printed output and an optional output source/concentration inventory tape. The following paragraphs describe the format and content of both forms of program output.

a. Printed Output. The SHORTZ program generates six categories of printed output, two of which are tables of average ground-level concentration. All program printed output is optional except warning and error messages. The printed output categories are:

- Input control data
- Input source data
- Input meteorological data
- Concentrations calculated at the base meteorological data input rate
- Concentrations calculated for up to three additional averaging times
- Warning and error messages

The first line of each page of output contains the run title (TITLE) and page number followed by the major heading of the type or category of output table.

The first category of printed output is the input program control card data. This output is optional and is selected by the option parameter ISW(6). Figure 3-2 shows an example of the printed program control input data. The example output shown in this section is output generated from an example problem given in Section 2.6. The second category of printed output is the source input data. Figure 3-3 shows an example of the source input data table. The third category of printed output is the meteorological input data. This output is controlled by the option ISW(8) and is illustrated in Figure 3-4. The fourth through fifth categories of output tables are concentration tables. Figure 3-5 through 3-10 shown an example of each type of output table. These tables are defined by their respective headings and are all optional, depending on the parameters ISW(2), ISW(3), ISW(4) and ISW(5). The warning and error messages produced by the program are generated by data errors within the SHORTZ program and are generally not associated with errors detected by the computer system on which the program is being run. These errors are given in Section 3.2.6 below.

b. Master Tape Inventory Output. The SHORTZ program will, on option, generate an output master source/concentration inventory tape. This file may be a permanent file or a temporary file, depending on what the user desires and requirements of the program. This data tape is written only if the parameter KSW equals "2" or "3" and the data are written to the FORTRAN logical unit specified by NOTFL. The data are written using the UNIVAC 1110 NTRAN binary write routines and tapes must be assigned with the W option to place a write-ring in the output tape. The format and contents of the SHORTZ input/output tape are shown in Table 3-6. This table gives the Logical Record, Word Number, Parameter Name and whether the data are in an integer or floating point (real) format. The logical record gives the order the respective records are written to tape and does not imply the physical (block) length actually on the tape. The physical block length of each tape record is 2000 UNIVAC 1110 words.

```
                    EXAMPLE SHORT TERM PROBLEM                                                DATE 040679, CASE  1, PAGE    1
                                                TABLE    1

                                           - GENERAL INPUT DATA -
     NUMBER OF INPUT SOURCES                                         (NSOURC) =     3
     NUMBER OF X GRID COORDINATES                                    (NXPNTS) =    17
     NUMBER OF Y GRID COORDINATES                                    (NYPNTS) =    15
     TOTAL NUMBER OF HOURS IN EACH DAY                               (NHOURS) =    24
     NUMBER OF DAYS OR CASES                                         ( NDAYS) =     1
     NUMBER OF CONCENTRATION REPORTS (SOURCE COMBINATIONS)           (NGROUP) =     5
     NUMBER OF DISCRETE CALCULATION POINTS                           (NXWYPT) =     1
     MET DATA INPUT CARD RATE (1=HOURLY,2=2 HOURLY,ETC)              (ISW(1)) =     1
     IS CONCENTRATION CALCULATED AT BASE RATE PRINTED                (ISW(2)) =     1
     NO  OF HOURS IN FIRST AVERAGE CONCENTRATION PRINTED             (ISW(3)) =     3
     NO  OF HOURS IN SECOND AVERAGE CONCENTRATION PRINTED            (ISW(4)) =    24
     NO  OF HOURS IN THIRD AVERAGE CONCENTRATION PRINTED             (ISW(5)) =     0
     ARE TERRAIN ELEVATION HEIGHTS USED                              (ISW(7)) =     1
     IS WIND SPEED TERRAIN FOLLOWING                                 (ISW(9)) =     0
     ARE CONCENTRATIONS AVERAGED OVER DAYS OR CASES                  (ISW(11))=     0
     IS THE FORMAT FOR SOURCE DATA READ                              (ISW(12))=     0
     IS COORDINATE SYSTEM CARTESIAN (=0) OR POLAR (=1)               (ISW(13))=     0
     ARE DISCRETE RECEPTORS CARTESIAN (=0) OR POLAR (=1)             (ISW(14))=     0
     ARE SOURCE COORDINATES CARTESIAN (=0) OR POLAR (=1)             (ISW(15))=     0
     MODEL UNITS CONVERSION FACTOR                                   (   TK   ) =  .1000000+07
     ACCELERATION OF GRAVITY                                         (   G    ) =  9.8000       (METERS/SEC**2)
     HEIGHT OF MEASUREMENT OF WIND SPEED, ETC                        (   ZR   ) =  6.0960       (METERS)
     ENTRAINMENT COEFFICIENT FOR UNSTABLE ATMOSPHERE                 (GAMMA1) =  .600
     ENTRAINMENT COEFFICIENT FOR STABLE ATMOSPHERE                   (GAMMA2) =  .660
     DISTANCE OVER WHICH RECTILINEAR PLUME EXPANSION OCCURS          ( XRY   ) = 50.0000        (METERS)
     DECAY COEFFICIENT FOR PHYSICAL OR CHEMICAL DEPLETION            (DECAY ) =,  .00000000
     ANGULAR DISPL OF GRID SYSTEM FROM TRUE NORTH                    (ROTATE) =    .683
     ELEVATION OF BASE OF WEATHER STATION                                (HA) =  366.70        (METERS)
     X ORIGIN OF POLAR COORDINATES                                     (UTMX) =         .00    (METERS)
     Y ORIGIN OF POLAR COORDINATES                                     (UTMY) =         .00    (METERS)
              *-* COORDINATE SYSTEM X AXIS (METERS) *-*

 60200000+06,   60300000+06,   .60400000+06,   60450000+06,   .60500000+06,   .60550000+06,   .60600000+06,   60650000+06,
 60700000+06,   .60750000+06,   60800000+06,   60850000+06,   60900000+06,   .60950000+06,   .61000000+06,   .61100000+06,
 61200000+06,
              *-* COORDINATE SYSTEM Y AXIS (METERS) *-*

 44870000+07,   .44880000+07,   44885000+07,   .44890000+07,   .44895000+07,   .44900000+07,   44905000+07,   44910000+07,
 44915000+07,   44920000+07,   44930000+07,   .44940000+07,   .44950000+07,   .44960000+07,   .44970000+07,
                                  *-* COORDINATES OF DISCRETE POINTS (METERS,METERS) *-*

 (X,Y) = ( 605167.0, 4489107.0), (
       NUMBER OF SOURCES IN EACH CONCENTRAIION REPORT GROUP 1 TO   5 =   1,   1,   1,   1,   1,
       SOURCE NUMBERS FOR EACH OF THE ABOVE GROUPS =    116,    117,    118,   -117,   -118,
```

FIGURE 3-2. Example listing of input data for the calculation of hourly, 3-hour and 24-hour ground-level concentration.

```
                          EXAMPLE SHORT TERM PROBLEM                                              DATE 040679, CASE  1, PAGE    2

                                                       TABLE    2

                                               - GENERAL INPUT DATA -

                                      *-* GRID SYSTEM TERRAIN HEIGHTS (METERS) *-*

                                             - GRID SYSTEM X AXIS (METERS) -
                   602000.000   603000.000   604000.000   604500.000   605000.000   605500.000   606000.000   606500.000   607000.000
 Y AXIS (METERS)                                               - HEIGHT -
                 -------------------------------------------------------------------------------------------------------------------

   4497000.000     329.0000000  347.0000000  320.0000000  235.0000000  259.0000000  311.0000000  296.0000000  280.0000000  280.0000000
   4496000.000     349.0000000  317.0000000  323.0000000  308.0000000  229.0000000  241.0000000  290.0000000  267.0000000  256.0000000
   4495000.000     317.0000000  363.0000000  364.0000000  265.0000000  238.0000000  232.0000000  226.0000000  226.0000000  232.0000000
   4494000.000     286.0000000  349.0000000  232.0000000  226.0000000  285.0000000  293.0000000  299.0000000  329.0000000  323.0000000
   4493000.000     305.0000000  244.0000000  229.0000000  250.0000000  305.0000000  274.0000000  268.0000000  296.0000000  300.0000000
   4492000.000     311.0000000  344.0000000  226.0000000  244.0000000  286.0000000  296.0000000  229.0000000  299.0000000  280.0000000
   4491500.000     326.0000000  317.0000000  229.0000000  238.0000000  268.0000000  235.0000000  286.0000000  305.0000000  338.0000000
   4491000.000     335.0000000  320.0000000  226.0000000  235.0000000  258.0000000  244.0000000  293.0000000  326.0000000  338.0000000
   4490500.000     354.0000000  290.0000000  226.0000000  232.0000000  229.0000000  282.0000000  296.0000000  335.0000000  320.0000000
   4490000.000     338.0000000  308.0000000  232.0000000  229.0000000  229.0000000  290.0000000  323.0000000  280.0000000  280.0000000
   4489500.000     288.0000000  296.0000000  290.0000000  226.0000000  232.0000000  229.0000000  238.0000000  244.0000000  250.0000000
   4489000.000     241.0000000  308.0000000  253.0000000  226.0000000  238.0000000  268.0000000  314.0000000  262.0000000  274.0000000
   4488500.000     250.0000000  259.0000000  230.0000000  226.0000000  262.0000000  282.0000000  320.0000000  370.0000000  274.0000000
   4488000.000     230.0000000  230.0000000  226.0000000  229.0000000  274.0000000  349.0000000  360.0000000  305.0000000  366.0000000
   4487000.000     358.0000000  347.0000000  317.0000000  341.0000000  375.0000000  396.0000000  332.0000000  351.0000000  387.0000000

                                             - GRID SYSTEM X AXIS (METERS) -
                   607500.000   608000.000   608500.000   609000.000   609500.000   610000.000   611000.000   612000.000
 Y AXIS (METERS)                                               - HEIGHT -
                 -------------------------------------------------------------------------------------------------------------------

   4497000.000     302.0000000  290.0000000  229.0000000  226.0000000  254.0000000  314.0000000  335.0000000  344.0000000
   4496000.000     232.0000000  232.0000000  229.0000000  268.0000000  323.0000000  308.0000000  338.0000000  344.0000000
   4495000.000     286.0000000  235.0000000  293.0000000  296.0000000  311.0000000  274.0000000  290.0000000  323.0000000
   4494000.000     314.0000000  323.0000000  274.0000000  290.0000000  288.0000000  296.0000000  308.0000000  326.0000000
   4493000.000     274.0000000  290.0000000  271.0000000  290.0000000  286.0000000  317.0000000  320.0000000  396.0000000
   4492000.000     399.0000000  349.0000000  305.0000000  283.0000000  283.0000000  293.0000000  360.0000000  363.0000000
   4491500.000     369.0000000  363.0000000  360.0000000  354.0000000  290.0000000  320.0000000  369.0000000  335.0000000
   4491000.000     323.0000000  320.0000000  379.0000000  372.0000000  372.0000000  277.0000000  344.0000000  329.0000000
   4490500.000     290.0000000  323.0000000  315.0000000  354.0000000  311.0000000  314.0000000  290.0000000  296.0000000
   4490000.000     274.0000000  265.0000000  311.0000000  355.0000000  354.0000000  347.0000000  335.0000000  360.0000000
   4489500.000     241.0000000  329.0000000  293.0000000  347.0000000  354.0000000  360.0000000  372.0000000  366.0000000
   4489000.000     250.0000000  290.0000000  363.0000000  329.0000000  293.0000000  347.0000000  314.0000000  366.0000000
   4488500.000     250.0000000  241.0000000  305.0000000  286.0000000  326.0000000  372.0000000  335.0000000  381.0000000
   4488000.000     317.0000000  296.0000000  247.0000000  280.0000000  366.0000000  354.0000000  373.0000000  320.0000000
   4487000.000     305.0000000  290.0000000  381.0000000  300.0000000  256.0000000  286.0000000  305.0000000  375.0000000
```

FIGURE 3-2. (Continued)

```
                    EXAMPLE SHORT TERM PROBLEM                                                    DATE 040679, CASE  1, PAGE    3

                                                        TABLE    2 (CONT)

                                                    - GENERAL INPUT DATA -

                                         *-* DISCRETE POINT TERRAIN HEIGHTS (METERS) *-*
    X          Y          HEIGHT               X          Y          HEIGHT                 X          Y          HEIGHT
 (METERS)   (METERS)                       (METERS)   (METERS)                          (METERS)   (METERS)
            ------------------------------------------------------------------------------------------------------------------

605167.0   4489107.0   274.0000000
```

FIGURE 3-2. (Continued)

```
                               FXAMPLE SHORT TFRM PROBLEN                                             DATE 040679, CASE  1, PAGE    4

                                                                       TABLE    3

                                                               - SOURCE INPUT DATA -

                                                              - SOURCE INVENTORY -
C T SOURCE T    SOURCE        X           Y        HEIGHT  IF TYPE=0     IF TYPE=0     ANGLE    STACK    ELEVATION  PARTICULATE DISTRIBUTION
A P NUMBER Y   STRENGTH   COORDINATE  COORDINATE   ABOVE   TEMP (DEG K)  VOL. EMISS     TO      INNER       AT        SETTLING    FREQUENCY
R P        P(GRAMS/SEC)   (METERS)    (METERS)     GROUND  IF TYPE=1OR2  RT  M**3/SEC  LONG     RADIUS     STACK      VELOCITY        OF
D E        E                                      (METERS) LENGTH SHORT  IF TYPE=1OR2  SIDE    (METERS)    BASE     (METERS/SEC) OCCURRENCE
                                                           SIDE (MTRS)   LENGTH LONG   (DEG)              (METERS)                (FRACTION)
                                                                         SIDE (MTRS)
----------------------------------------------------------------------------------------------------------------------------------------------
X       116 0    318.150   604380.00  4488740.00    67.10    472.000       160.980        0     2.600     229.00
X       117 0    318.150   604380.00  4488740.00    62.50    444.000       162.140        0     1.850     229.00
X       118 0   1260.000   602330.00  4487800.00   229.00    411.000       881.460        0     3.200     229.00
```

FIGURE 3-3. Example listing of input sources used in the calculation of hourly, 3-hour and 24-hour ground-level concentration.

```
                                        EXAMPLE SHORT TERM PROBLEM                                         DATE 040679, CASE  1, PAGE    5

                                                             TABLE    4

                                                   - METEOROLOGICAL INPUT DATA -

HOUR     WIND        WIND      LAYER     AMBIENT   VERT GRAD  STAB   WND SPD     STD DEV EL    STD DEV AZ    STD DEV EL    STD DEV AZ       LATERAL
       DIRECTION    SPEED      DEPTH       TEMP    OF POT TMP ILITY POWER LAW   ANGLE, SOR    ANGLE, SOR    ANGLE, SOR    ANGLE, SOR     DIFFUSION
       (DEGREES)  (MTR/SEC)  (METERS)   (DEG K)   (DEG K/M)  CAT   EXPONENT     TYPE 0        TYPE 0       TYPE 1OR2     TYPE 1OR2    COEFFICIENT
         THETA       UBAR        HM         TA        DPDZ    ISTBLE    P      SIGEPU(RAD)  SIGAPU(RAD)  SIGEPL(RAD)  SIGAPL(RAD)       ALPHA
----------------------------------------------------------------------------------------------------------------------------------------------------
 100  170.0000     5.4017    953.000   283.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
 200  190.0000     6.6878   1068.000   284.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
 300  210.0000    10.0316   1184.000   285.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
 400  220.0000     9.7744   1299.000   285.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
 500  245.0000     8.2311   1415.000   283.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
 600  255.0000     9.2630   1530.000   282.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
 700  255.0000     9.7744   1645.000   280.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
 800  250.0000    10.2889   1598.000   280.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
 900  250.0000     9.0078   1551.000   280.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
1000  250.0000     8.4993   1504.000   279.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
1100  250.0000     8.2311   1457.000   279.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
1200  250.0000     7.2022   1410.000   279.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
1300  250.0000     9.2630   1363.000   279.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
1400  250.0000     7.7167   1316.000   278.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
1500  255.0000     6.6878   1269.000   278.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
1600  260.0000     6.1733   1221.000   277.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
1700  260.0000     7.7167   1174.000   276.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
1800  265.0000     6.6878   1127.000   276.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
1900  260.0000     7.7167   1080.000   275.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
2000  250.0000     6.6878   1033.000   275.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
2100  250.0000     5.9161    986.000   275.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
2200  240.0000     6.1733    939.000   275.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
2300  260.0000     6.1733    892.000   274.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
   0  270.0000     5.9161    845.000   274.000      .0000           .1700      .0735000      .1051000      .0735000      .1051000        .9000
```

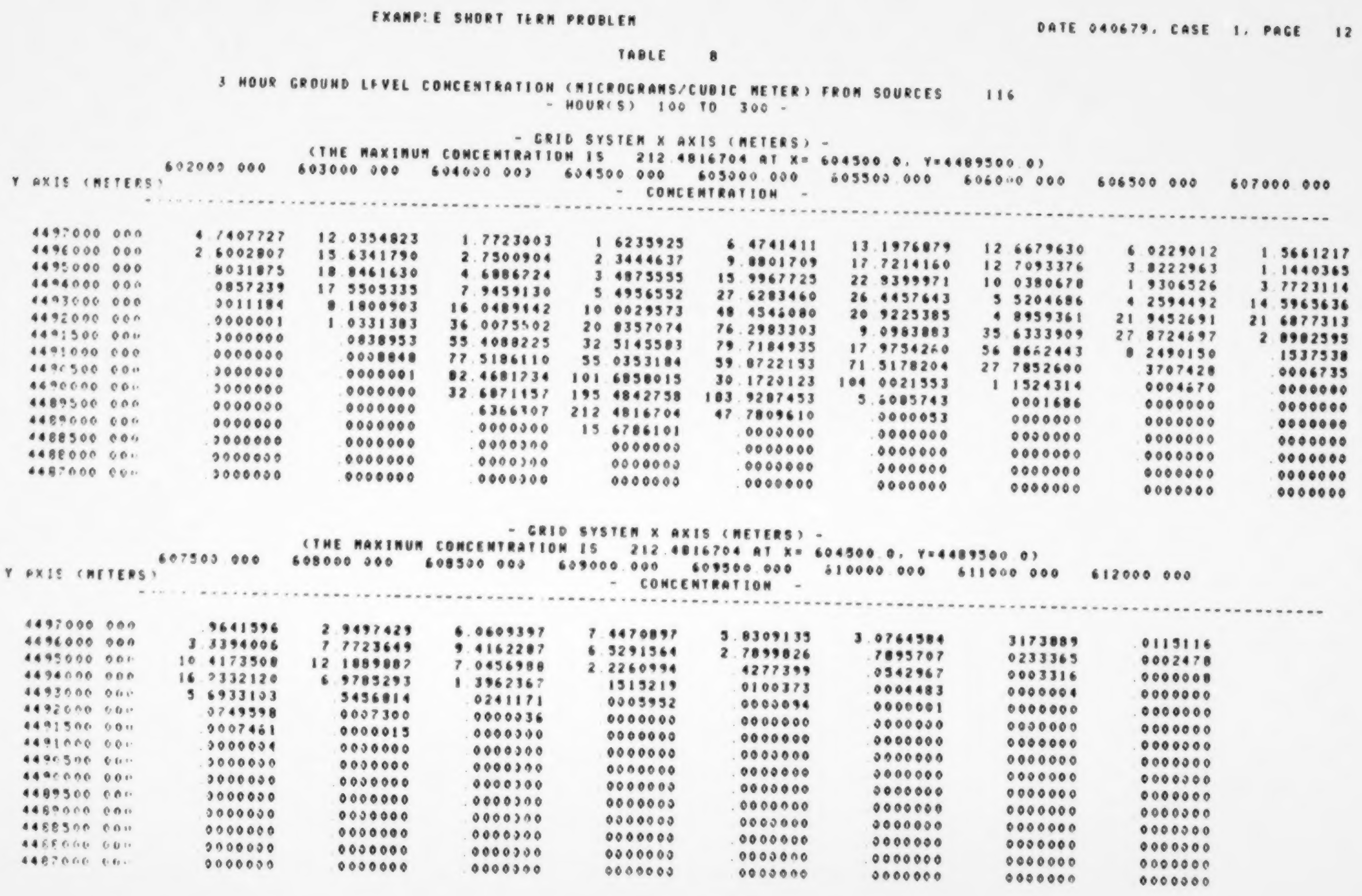
FIGURE 3-4. Example listing of the hourly input data.

```
                    EXAMPLE SHORT TERM PROBLEM                                                   DATE 040679, CASE  1, PAGE    6

                                                        TABLE    5

                  1 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES    116
                                                  - HOUR(S)  100 TO  100 -

                                               - GRID SYSTEM X AXIS (METERS) -
                              (THE MAXIMUM CONCENTRATION IS   247.3997192 AT X= 604000.0, Y=4490500.0)
                   602000.000    603000.000    604000.000    604500.000    605000.000    605500.000    606000.000    606500.000    607000.000
Y AXIS (METERS)                                             -  CONCENTRATION  -
                 -------------------------------------------------------------------------------------------------------------------------

4497000.000      14.2223183    36.1061482     4.8805170      .5190239      .0241774      .0004504      .0000030      .0000000      .0000000
4496000.000       7.8008422    46.9024491     7.7789170      .6940785      .0197872      .0001820      .0000005      .0000000      .0000000
4495000.000       2.4095625    56.5384755    13.5737340      .9007787      .0144357      .0000492      .0000000      .0000000      .0000000
4494000.000        .2571718    52.6516004    23.3759339     1.1663914      .0086095      .0000068      .0000000      .0000000      .0000000
4493000.000        .0033553    24.5402713    47.7679605     1.6394942      .0031775      .0000002      .0000000      .0000000      .0000000
4492000.000        .0000003     3.0994149   107.8097582     2.1492204      .0003859      .0000000      .0000000      .0000000      .0000000
4491500.000        .0000000      .2516859   166.1096191     2.2946029      .0000525      .0000000      .0000000      .0000000      .0000000
4491000.000        .0000000      .0026543   232.5167007     2.2064084      .0000019      .0000000      .0000000      .0000000      .0000000
4490500.000        .0000000      .0000003   247.3997192     1.5866858      .0000000      .0000000      .0000000      .0000000      .0000000
4490000.000        .0000000      .0000000    98.0614033      .4682311      .0000000      .0000000      .0000000      .0000000      .0000000
4489500.000        .0000000      .0000000     1.9098921      .0023835      .0000000      .0000000      .0000000      .0000000      .0000000
4489000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4488500.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4488000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4487000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000

                                               - GRID SYSTEM X AXIS (METERS) -
                              (THE MAXIMUM CONCENTRATION IS   247.3997192 AT X= 604000.0, Y=4490500.0)
                   607500.000    608000.000    608500.000    609000.000    609500.000    610000.000    611000.000    612000.000
Y AXIS (METERS)                                             -  CONCENTRATION  -
                 -------------------------------------------------------------------------------------------------------------------------

4497000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4496000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4495000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4494000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4493000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4492000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4491500.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4491000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4490500.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4490000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4489500.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4489000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4488500.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4488000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
4487000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
```

FIGURE 3-5. Example listing of 1-hour ground-level concentration from a single source.

```
                    EXAMPLE SHORT TERM PROBLEM                                              DATE 040679, CASE  1, PAGE    7

                                                       TABLE    5 (CONT)

               1 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES    116
                                                 - HOUR(S)  100 TO  100 -

                                                  - DISCRETE POINT RECEPTORS -
                          (THE MAXIMUM CONCENTRATION IS.      0000000 AT X= 605167.0, Y=4489107.0)
    X          Y       CONCENTRATION          X         Y        CONCENTRATION          X          Y       CONCENTRATION
 (METERS)   (METERS)                      (METERS)  (METERS)                        (METERS)   (METERS)
 ------------------------------------------------------------------------------------------------------------------------

 605167.0  4489107.0       .0000000
```

FIGURE 3-5. (Continued)



```
                       EXAMPLE SHORT TERM PROBLEM                                           DATE 040679, CASE  1, PAGE   12
                                                    TABLE    8

              3 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES    116
                                                 - HOUR(S)  100 TO  300 -

                                                - GRID SYSTEM X AXIS (METERS) -
                             (THE MAXIMUM CONCENTRATION IS   212.4816704 AT X= 604500.0, Y=4489500.0)
                 602000.000   603000.000   604000.000   604500.000   605000.000   605500.000   606000.000   606500.000   607000.000
Y AXIS (METERS)
                                                       -  CONCENTRATION  -
                 ----------------------------------------------------------------------------------------------------------------

  4497000.000      4.7407727   12.0354823    1.7723003    1.6235925    6.4741411   13.1976879   12.6679630    6.0229012    1.5661217
  4496000.000      2.6002807   15.6341790    2.7500904    2.3444637    9.8801709   17.7214160   12.7093376    3.8222963    1.1440365
  4495000.000       .8031875   18.8461630    4.6886724    3.4875555   15.9967725   22.9399971   10.0380678    1.9306526    3.7723114
  4494000.000       .0857239   17.5505335    7.9459130    5.4956552   27.6283460   26.4457643    5.5204686    4.2594492   14.5965636
  4493000.000       .0011184    8.1800903   16.0489142   10.0029573   48.4546080   20.9225385    4.8959361   21.9452691   21.6877313
  4492000.000       .0000001    1.0331383   36.0075502   20.8357074   76.2983303    9.0983883   35.6333909   27.8724697    2.8982595
  4491500.000       .0000000     .0838953   55.4088225   32.5145583   79.7184935   17.9754260   56.8662443    8.2490150     .1537538
  4491000.000       .0000000     .0008848   77.5186110   55.0353184   59.8722153   71.5178204   27.7852600     .3707428     .0006735
  4490500.000       .0000000     .0000001   82.4681234  101.6858015   30.1720123  104.0021553    1.1524314     .0004670     .0000000
  4490000.000       .0000000     .0000000   32.6871157  195.4842758  183.9287453    5.6085743     .0001686     .0000000     .0000000
  4489500.000       .0000000     .0000000     .6366307  212.4816704   47.7809610     .0000053     .0000000     .0000000     .0000000
  4489000.000       .0000000     .0000000     .0000000   15.6786101     .0000000     .0000000     .0000000     .0000000     .0000000
  4488500.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4488000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4487000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000

                                                - GRID SYSTEM X AXIS (METERS) -
                             (THE MAXIMUM CONCENTRATION IS   212.4816704 AT X= 604500.0, Y=4489500.0)
                 607500.000   608000.000   608500.000   609000.000   609500.000   610000.000   611000.000   612000.000
Y AXIS (METERS)
                                                       -  CONCENTRATION  -
                 ----------------------------------------------------------------------------------------------------------------

  4497000.000       .9641596    2.9497429    6.0609397    7.4470897    5.8309135    3.0764584     .3173889     .0115116
  4496000.000      3.3394006    7.7723649    9.4162287    6.5291564    2.7899826     .7895707     .0233365     .0002478
  4495000.000     10.4173508   12.1889887    7.0456988    2.2260994     .4277399     .0542967     .0003316     .0000008
  4494000.000     16.2332120    6.9785293    1.3962367     .1515219     .0100373     .0004483     .0000004     .0000000
  4493000.000      5.6933103     .5456814     .0241171     .0005952     .0000094     .0000001     .0000000     .0000000
  4492000.000       .0749598     .0007300     .0000036     .0000000     .0000000     .0000000     .0000000     .0000000
  4491500.000       .0007461     .0000015     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4491000.000       .0000004     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4490500.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4490000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4489500.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4489000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4488500.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4488000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4487000.000       .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
```

FIGURE 3-6. Example listing of 3-hour average ground-level concentration from a single source.

```
                     EXAMPLE SHORT TERM PROBLEM
                                                                             DATE 040679, CASE  1, PAGE   13
                                              TABLE    8 (CONT)
                3 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES    116
                                           - HOUR(S)  100 TO  300 -

                                                 - DISCRETE POINT RECEPTORS -
                        (THE MAXIMUM CONCENTRATION IS.      0000000 AT X= 605167 0, Y=4489107 0)
    X          Y      CONCENTRATION        X          Y       CONCENTRATION         X          Y       CONCENTRATION
 (METERS)  (METERS)                     (METERS)  (METERS)                       (METERS)  (METERS)
        ------------------------------  ---------------------------------------------------------------------------

605167 0  4489107 0      0000000
```

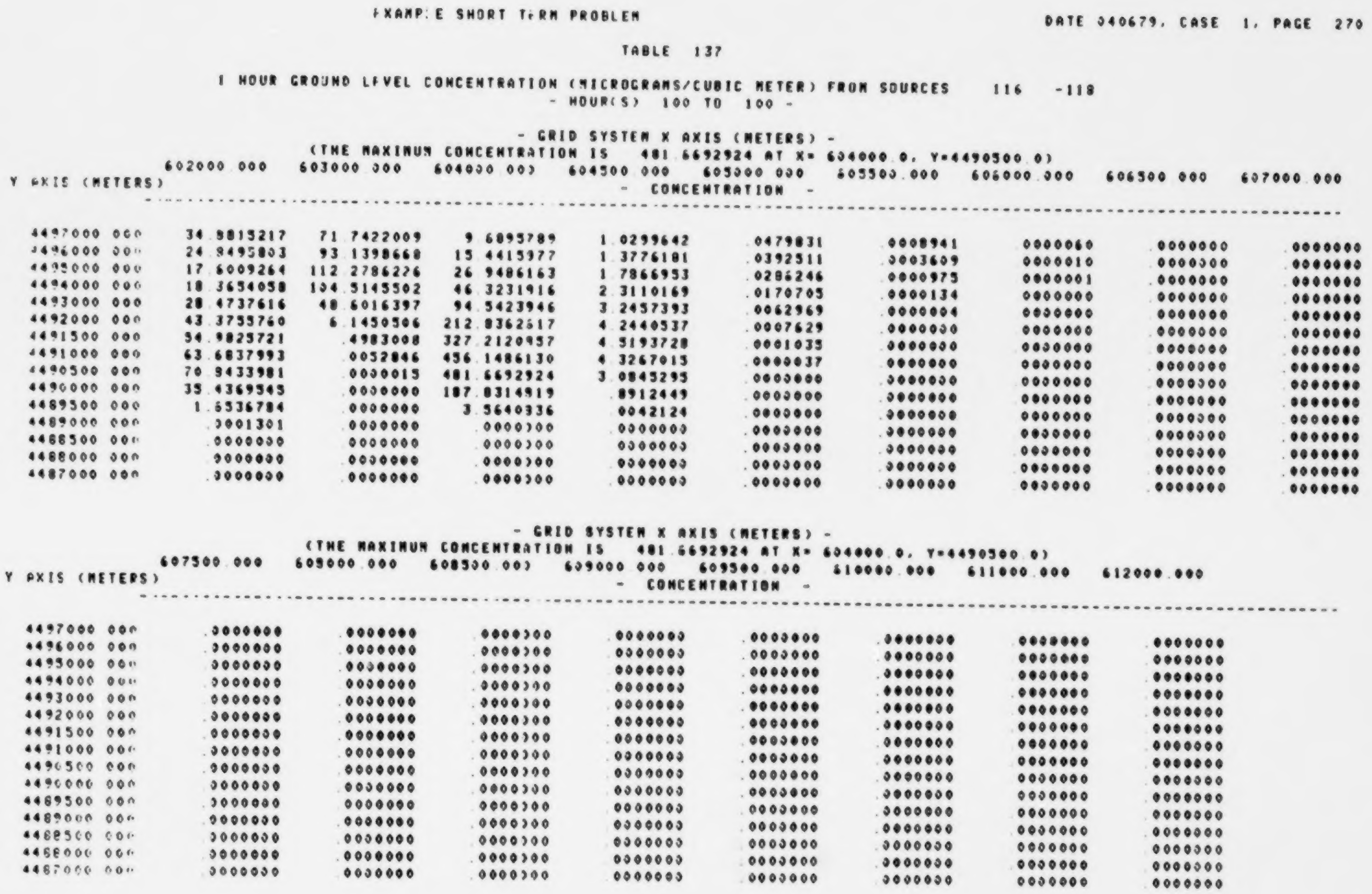
FIGURE 3-6. (Continued)

```
                EXAMPLE SHORT TERM PROBLEM                                                      DATE 040679, CASE  1, PAGE   70
                                                          TABLE   37
            24 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES     116
                                                - HOUR(S)  100 TO     0 -

                                            - GRID SYSTEM X AXIS (METERS) -
                               (THE MAXIMUM CONCENTRATION IS   703.9800262 AT X= 605000.0, Y=4489000.0)
               602000.000   603000.000   604000.000   604500.000   605000.000   605500.000   606000.000   606500.000   607000.000
Y AXIS (METERS)
                                                          -  CONCENTRATION  -
       -----------------------------------------------------------------------------------------------------------------------

 4497000.000     .3925966    1.5044353     .2215375     .2029491     .8092676    1.5497110    1.5834954     .7528627     .1957653
 4496000.000     .3250351    1.9542724     .3437613     .2930580    1.2350214    2.2151770    1.5886672     .4777971     .1430094
 4495000.000     .1003984    2.3557704     .5860776     .4359444    1.9995966    2.8549996    1.2547585     .2413335     .4718228
 4494000.000     .0107155    2.1938167     .9932391     .6869569    3.4535432    3.3057205     .6900590     .5326697    1.8408720
 4493000.000     .0001398    1.0225113    2.0061180    1.2503697    6.0568260    2.6153173     .6121427    2.7726109    3.2921273
 4492000.000     .0000000     .1291423    4.5009438    2.6044634    9.5372913    1.1373488    4.5135794    5.2621849    4.8503484
 4491500.000     .0000000     .0104869    6.9261028    4.0643199    9.9648117    2.2496497    8.0388374    6.9329135    3.3992249
 4491000.000     .0000000     .0001106    9.6898264    6.8794149    7.4840292    9.0961775   10.4509133    5.5114490    1.1426097
 4490500.000     .0000000     .0000000   10.3085134   12.7107252    3.7723840   18.4789855   10.1667010    2.4862293   11.5944065
 4490000.000     .0000000     .0000000    4.0858932   24.4355345   23.5662365   23.2355189    8.7311997   36.0789213   71.5563993
 4489500.000     .0000000     .0000000     .0795788   26.5602088   54.1036777   31.3448625  176.5285397  192.4517326  123.8642540
 4489000.000     .0000000     .0000000     .0000000    2.0146030  703.9800262  490.3607445  222.5909233   96.9381027   57.1596508
 4488500.000     .0000000     .0000000     .0000000     .0000000     .0004179    1.1893189    5.6338416    7.7552179    6.6504030
 4488000.000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000022     .0006460     .0120165
 4487000.000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000

                                            - GRID SYSTEM X AXIS (METERS) -
                               (THE MAXIMUM CONCENTRATION IS   703.9800262 AT X= 605000.0, Y=4489000.0)
               607500.000   608000.000   608500.000   609000.000   609500.000   610000.000   611000.000   612000.000
Y AXIS (METERS)
                                                          -  CONCENTRATION  -
       -----------------------------------------------------------------------------------------------------------------------

 4497000.000     .1205286     .3690118     .7620260     .9642984     .8712342     .7558340     .8099805     .4795276
 4496000.000     .4177238     .9779699    1.2349757    1.0730993     .9768599    1.0377846     .6650561     .1539795
 4495000.000    1.3120892    1.6332024    1.3763445    1.3519496    1.3465432     .9755361     .1934250     .1341335
 4494000.000    2.2635725    1.8939367    1.9466137    1.5292838     .7423254     .2520653     .2905230    1.0955610
 4493000.000    2.9139365    2.5960234    1.2115985     .3447772     .2888296     .7725684    2.3680208    3.7935487
 4492000.000    2.2827418     .5253641     .9010517    2.4378248    4.1883587    5.7801704    9.8890212   13.5336242
 4491500.000     .7158907    1.8991510    4.7386709    7.4601717   10.3277736   14.0069797   19.1290677   17.5970662
 4491000.000    4.4013931    9.5842267   14.8854631   21.3618598   26.7578478   28.3180790   23.1287284   15.9462842
 4490500.000   22.4246893   36.0867000   45.3379955   44.9431529   38.2155601   30.4879930   19.2424331   13.2881503
 4490000.000   87.2355785   73.9471254   55.4492064   40.6045561   30.7199755   24.1053433   15.8505509   10.9282850
 4489500.000   77.1925276   55.7817783   39.3821301   29.2389314   21.9904919   16.8919060   10.5752736    7.1162280
 4489000.000   34.9213157   24.8580377   18.4491527   13.7789297   10.5927154    8.5642976    5.7936429    4.2427261
 4488500.000    5.9596484    5.3525183    5.1359760    4.4392172    3.9732603    3.5169147    2.7541972    2.2460218
 4488000.000     .0546511     .1355376     .2301332     .3511582     .4661966     .5462085     .6486202     .6844335
 4487000.000     .0000000     .0000000     .0000302     .0000041     .0000330     .0001659     .0014641     .0058392
```

FIGURE 3-7. Example listing of 24-hour average ground-level concentration from a single source.

```
                    EXAMPLE SHORT TERM PROBLEM                                                   DATE 040679, CASE  1, PAGE   71

                                                   TABLE   37 (CONT)

              24 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES    116
                                             - HOUR(S)  100 TO    0 -

                                               - DISCRETE POINT RECEPTORS -
                           (THE MAXIMUM CONCENTRATION IS,  719.1866608 AT X= 605167.0, Y=4489107.0)
    X          Y        CONCENTRATION          X          Y       CONCENTRATION            X          Y        CONCENTRATION
 (METERS)   (METERS)                       (METERS)   (METERS)                          (METERS)   (METERS)
 ---------------------------------------------------------------------------------------------------------------------------

605167.0  4489107.0   719.1866608
```

FIGURE 3-7. (Continued)



```
             EXAMPLE SHORT TERM PROBLEM                                              DATE 040679, CASE  1, PAGE  270
                                                          TABLE  137

                 1 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES    116   -118
                                                    - HOUR(S)  100 TO  100 -

                                                 - GRID SYSTEM X AXIS (METERS) -
                                  (THE MAXIMUM CONCENTRATION IS   481.6692924 AT X= 604000.0, Y=4490500.0)
                   602000.000   603000.000   604000.000   604500.000   605000.000   605500.000   606000.000   606500.000   607000.000
Y AXIS (METERS)                                            -  CONCENTRATION  -
          ------------------------------------------------------------------------------------------------------------------

  4497000.000      34.9815217   71.7422009    9.6095789    1.0299642     .0479831     .0008941     .0000060     .0000000     .0000000
  4496000.000      24.8495803   93.1398668   15.4415977    1.3776181     .0392511     .0003609     .0000010     .0000000     .0000000
  4495000.000      17.6009264  112.2786226   26.9486163    1.7866953     .0286246     .0000975     .0000001     .0000000     .0000000
  4494000.000      18.3654058  104.5145502   46.3231916    2.3110169     .0170705     .0000134     .0000000     .0000000     .0000000
  4493000.000      28.4737616   48.6016397   94.5423946    3.2457393     .0062969     .0000004     .0000000     .0000000     .0000000
  4492000.000      43.3755760    6.1450506  212.8362617    4.2440537     .0007629     .0000000     .0000000     .0000000     .0000000
  4491500.000      54.9825721     .4983008  327.2120957    4.5193728     .0001035     .0000000     .0000000     .0000000     .0000000
  4491000.000      63.6837993     .0052846  456.1486130    4.3267015     .0000037     .0000000     .0000000     .0000000     .0000000
  4490500.000      70.9433981     .0000015  481.6692924    3.0845295     .0000000     .0000000     .0000000     .0000000     .0000000
  4490000.000      35.4369545     .0000000  187.8314919     .8912449     .0000000     .0000000     .0000000     .0000000     .0000000
  4489500.000       1.6536784     .0000000    3.5640336     .0042124     .0000000     .0000000     .0000000     .0000000     .0000000
  4489000.000        .0001301     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4488500.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4488000.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4487000.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000

                                                 - GRID SYSTEM X AXIS (METERS) -
                                  (THE MAXIMUM CONCENTRATION IS   481.6692924 AT X= 604000.0, Y=4490500.0)
                   607500.000   608000.000   608500.000   609000.000   609500.000   610000.000   611000.000   612000.000
Y AXIS (METERS)                                            -  CONCENTRATION  -
          ------------------------------------------------------------------------------------------------------------------

  4497000.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4496000.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4495000.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4494000.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4493000.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4492000.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4491500.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4491000.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4490500.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4490000.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4489500.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4489000.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4488500.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4488000.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
  4487000.000        .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000     .0000000
```

FIGURE 3-8. Example listing of 1-hour average ground-level concentration from combined sources.

```
                    EXAMPLE SHORT TERM PROBLEM                                                   DATE 040679, CASE  1, PAGE  271

                                                       TABLE  137 (CONT)

                    1 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES    116   -118
                                                 - HOUR(S)  100 TO  100 -

                                                 - DISCRETE POINT RECEPTORS -
                          (THE MAXIMUM CONCENTRATION IS,     .0000000 AT X= 605167.0, Y=4489107.0)
    X          Y       CONCENTRATION            X          Y       CONCENTRATION            X          Y       CONCENTRATION
 (METERS)   (METERS)                         (METERS)   (METERS)                         (METERS)   (METERS)
 ------------------------------------------------------------------------------------------------------------------------------

 605167.0  4489107.0      .0000000
```

FIGURE 3-8. (Continued)

```
                               EXAMP:E SHORT T+RM PROBLEM
                                                                                    DATE 040679, CASE  1, PAGE  276
                                                    TABLE  140

                     3 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES    116   -118
                                              - HOUR(S)  100 TO  300 -

                                                - GRID SYSTEM X AXIS (METERS) -
                          (THE MAXIMUM CONCENTRATION IS   207.9302254 AT X= 605000.0, Y=4490000.0)
                   602000.000    603000.000    604000.000    604500.000    605000.000    605500.000    606000.000    606500.000    607000.000
Y AXIS (METERS)
                                                             -  CONCENTRATION  -
            ------------------------------------------------------------------------------------------------------------------------------

 4497000.000      11.9214952    32.8519160    23.0818420    13.9296052    15.4833858    24.7864063    24.6326780    16.3917785    12.8999026
 4496000.000       8.6050647    43.1042785    25.6976349    12.9219583    19.4786899    33.3403630    28.9451919    18.8035270    15.8955890
 4495000.000       6.1914330    56.0053225    28.4187665    10.8120047    30.1717863    47.0169196    32.0039439    19.4228315    17.6420584
 4494000.000       6.4239085    61.9526024    26.1033714    12.0110348    56.6994219    66.3508072    30.5231218    19.4775474    32.2793274
 4493000.000       9.7675103    45.9963408    35.9953146    25.2128944   111.4355650    60.2097335    18.1695037    45.1647491    43.2654572
 4492000.000      14.6526688    53.9942660    77.4123990    64.4149351   138.4658890    22.3660617    68.7776365    55.1762581     5.7068982
 4491500.000      18.4731052    46.6511040   125.3925486    86.5455799   146.0422935    34.4103465   111.2155027    16.3206520      .3070998
 4491000.000      21.3149328    38.8658614   101.2756342   106.3523216   100.1964245   133.1252251    54.1937079      .7376625      .0013447
 4490500.000      23.6545410    14.8172786   105.5193462   156.0432739    48.6718345   196.3054446     2.2319825      .0009306      .0000001
 4490000.000      11.8183200     5.3800962    67.5071925   259.2849655   207.9302254    10.4081122      .0003319      .0000000      .0000000
 4489500.000        .5512687     4.1810619     1.2735915   227.1286526    62.7198563      .0000078      .0000000      .0000000      .0000000
 4489000.000        .0000434     4.5808513      .0000004    15.6786211      .0000000      .0000000      .0000000      .0000000      .0000000
 4488500.000        .0000000      .0000116      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
 4488000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
 4487000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000

                                                - GRID SYSTEM X AXIS (METERS) -
                          (THE MAXIMUM CONCENTRATION IS   207.9302254 AT X= 605000.0, Y=4490000.0)
                   607500.000    608000.000    608500.000    609000.000    609500.000    610000.000    611000.000    612000.000
Y AXIS (METERS)
                                                             -  CONCENTRATION  -
            ------------------------------------------------------------------------------------------------------------------------------

 4497000.000      13.0377913    15.3694067    17.3682945    17.1087151    12.4025868     6.3676609      .6436871      .0232200
 4496000.000      16.4542410    20.2799047    20.3890450    13.4582833     5.6720554     1.5923935      .0468998      .0004976
 4495000.000      24.9719577    25.2045050    14.2523674     4.4682071      .8573082      .1083827      .0006627      .0000016
 4494000.000      32.9345155    14.0018886     2.7783548      .3020139      .0200027      .0008944      .0000007      .0000000
 4493000.000      11.2716484     1.0841347      .0477901      .0011836      .0000187      .0000002      .0000000      .0000000
 4492000.000        .1499260      .0014598      .0000072      .0000000      .0000000      .0000000      .0000000      .0000000
 4491500.000        .0014921      .0000030      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
 4491000.000        .0000008      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
 4490500.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
 4490000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
 4489500.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
 4489000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
 4488500.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
 4498000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
 4487000.000        .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000      .0000000
```

FIGURE 3-9. Example listing of 3-hour average ground-level concentration from combined sources.

```
                        EXAMPLE SHORT TERM PROBLEM
                                                                                  DATE 040679, CASE  1, PAGE  277
                                                      TABLE  140 (CONT)

                  3 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES    116   -118
                                                  - HOUR(S)  100 TO  300 -

                                                  - DISCRETE POINT RECEPTORS -
                             (THE MAXIMUM CONCENTRATION IS,      .0000000 AT X= 605167.0, Y=4489107.0)
    X          Y         CONCENTRATION           X          Y         CONCENTRATION
 (METERS)   (METERS)                                                                       X          Y        CONCENTRATION
                                              (METERS)   (METERS)                       (METERS)   (METERS)
 ------------------------------------------------------------------------------------------------------------------------------

 605167.0  4489107.0      .0000000
```

FIGURE 3-9. (Continued)

```
                         EXAMPLE SHORT TERM PROBLEM
                                                                                      DATE 040679, CASE  1, PAGE  334
                                              TABLE  169
          24 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES    116   -118
                                    - HOUR(S)  100 TO    0 -

                                         - GRID SYSTEM X AXIS (METERS) -
                  (THE MAXIMUM CONCENTRATION IS   769.5804596 AT X= 605000.0, Y=4489000.0)
              602000.000   603000.000   604000.000   604500.000   605000.000   605500.000   606000.000   606500.000   607000.000
Y AXIS (METERS)
                                                  - CONCENTRATION -
        -----------------------------------------------------------------------------------------------------------------------

 4497000.000    1.4901869    4.1064896    2.8852352    1.7412007    1.9354232    3.0983017    3.0791243    2.0497705    1.6209821
 4496000.000    1.0756331    5.3980348    3.2122006    1.6152449    2.4348366    4.1675724    3.6190148    2.3722380    2.0687445
 4495000.000     .7739291    7.0006653    3.5523458    1.3516007    3.7714890    5.8779699    4.0168641    2.3620428    2.7526243
 4494000.000     .8029886    7.7440753    3.2629214    1.5013859    7.0883171    8.3207790    4.0808958    3.5341106    6.2062182
 4493000.000    1.2209398    5.7495426    4.4994183    3.1523104   13.9735695    8.0351313    4.1816562    8.7711712    8.9248053
 4492000.000    1.8315836    6.7492833    9.6769346    8.1145079   20.9369883    6.4372634   11.7990297   11.9292520    9.9612039
 4491500.000    2.3091381    5.8313880   15.6804131   11.2617369   21.4424553    8.0032524   17.4958479   14.1962066    7.6744608
 4491000.000    2.6643666    4.8582327   22.7462987   15.3156751   17.0742691   18.7719307   20.9059882   12.4249022    6.0718564
 4490500.000    2.9568176    1.8521598   23.9698915   23.5021236    7.9520917   35.4591842   21.9852304   11.0206898   31.3042350
 4490000.000    1.4772900     .6725178   11.2024745   34.1264186   37.3589253   46.9829498   25.9976337   81.1692581  160.1463108
 4489500.000     .0609086     .5232667    2.3345014   28.7927969   74.6695557   57.2447233  315.1406288  374.7251892  266.1494637
 4489000.000     .0000054     .6161549     .2956935    6.4945626  769.5804596  757.6824875  444.8111877  204.9749413  137.0868626
 4488500.000     .0000000     .0001355    2.7162903   12.3210129   28.6947649   36.9552728   49.4868937   54.9486156   36.0933471
 4488000.000     .0000000     .0000000     .2453974    1.8873233    7.8827643   17.9979925   18.0238020   12.8015842   14.4451220
 4487000.000     .0000000     .0000000     .0000000     .0000166     .0016617     .0189028     .0523162     .1466534     .3056920

                                         - GRID SYSTEM X AXIS (METERS) -
                  (THE MAXIMUM CONCENTRATION IS   769.5804596 AT X= 605000.0, Y=4489000.0)
              607500.000   608000.000   608500.000   609000.000   609500.000   610000.000   611000.000   612000.000
Y AXIS (METERS)
                                                  - CONCENTRATION -
        -----------------------------------------------------------------------------------------------------------------------

 4497000.000    1.7824900    2.1203345    2.6682525    3.0768493    3.0042033    2.7650784    2.2885469    1.1467753
 4496000.000    2.3744766    3.3213340    3.9142400    3.6631607    3.2553262    2.9227383    1.5433707     .4168908
 4495000.000    4.4379235    5.0984349    4.4612470    3.8334709    3.2715617    2.1825419     .5463220     .8927646
 4494000.000    6.9226111    5.4247691    4.6177773    3.3326081    1.6400502     .7884756    1.6638979    4.3100533
 4493000.000    6.7914154    5.5012497    2.6466936    1.2646800    1.7653763    3.9234314    8.0529495   12.7686396
 4492000.000    5.1720083    2.5305054    4.3403134    8.3785089   17.8706937   17.5763190   30.5239341   41.6000214
 4491500.000    3.9008028    7.9039735   14.9953520   22.3266997   29.9277182   40.7652674   56.5495200   53.8991661
 4491000.000   14.3437440   26.9075086   42.5889506   60.0234237   74.7040710   77.4122896   69.0681801   50.5578914
 4490500.000   56.7620497   92.4013386  115.8257465  120.0476980  104.6034613   87.4421043   58.3219848   41.5540743
 4490000.000  198.6539124  176.5683956  144.8966345  114.1143627   89.0980453   71.1390486   48.3127356   35.3835535
 4489500.000  178.7742443  144.6879330  103.9032574   82.9731398   65.3772964   52.6988010   36.2530050   26.3083158
 4489000.000   90.9726019   72.3106356   61.6357951   47.5351925   37.4559503   32.5167050   22.7806356   17.6958902
 4488500.000   29.9543056   25.8591118   25.4536176   21.3156509   19.3996863   17.5594947   13.2539219   10.9968960
 4488000.000   11.1153635    9.5793436    7.9254966    7.9751840    8.4880348    7.7687552    6.9364184    5.9110116
 4487000.000     .3644797     .4713473     .7421015     .7505664     .7901884     .9262431    1.0974742    1.2948734
```

FIGURE 3-10. Example listing of 24-hour average ground-level concentration from combined sources.

```
                        EXAMPLE SHORT TERM PROBLEM                                              DATE 040679, CASE  1, PAGE  335

                                                       TABLE  169 (CONT)

               24 HOUR GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) FROM SOURCES    116   -118
                                                  - HOUR(S)  100 TO    0 -

                                                  - DISCRETE POINT RECEPTORS -
                     (THE MAXIMUM CONCENTRATION IS,  978.8568726 AT X= 605167.0, Y=4489107.0)
    X          Y       CONCENTRATION          X          Y       CONCENTRATION           X          Y       CONCENTRATION
 (METERS)   (METERS)                      (METERS)   (METERS)                        (METERS)   (METERS)
 ---------------------------------------------------------------------------------------------------------------------------

 605167.0  4489107.0   978.8568726
```

FIGURE 3-10. (Continued)

TABLE 3-6

SHORTZ INPUT/OUTPUT TAPE FORMAT

Tape Logical Record	Word Number	Parameter Name	Integer (I)/ Floating Point (FP)
1	1	NSOURC	I
	2	NGROUP	I
	3	NXPNTS	I
	4	NYPNTS	I
	5	NXWYPT	I
	6	NHOURS	I
	7	NDAYS	I
	8	IOVRSN	I
2	1 - 20	ISW	I
	21 - 40	TITLE	I
	41 - 46	KUNR	I
	47 - 49	KFNR	I
3	1 - NXPNTS	X (X-axis)	FP
	NXPNTS+1 NXPNTS+NYPNTS	Y (Y-axis)	FP
	NXPNTS+NYPNTS+1 - NXPNTS+NYPNTS+ NXWYPT	X (discrete)	FP
	NXPNTS+NYPNTS+ NXWYPT+1 - NXPNTS+NYPNTS+ 2*NXWYPT	Y (discrete)	FP
4	1 - NXPNTS*NYPNTS	ZZ	FP
	NXPNTS*NYPNTS+1 - NXPNTS+NYPNTS+ NXWYPT	ZZ (discrete)	FP
5	1	ROTATE	FP
	2	TK	FP

TABLE 3-6 (Continued)

Tape Logical Record	Word* Number	Parameter Name	Integer (I)/ Floating Point (FP)
5 (Cont.)	3	G	FP
	4	ZR	FP
	5	HA	FP
	6	GAMMA1	FP
	7	GAMMA2	FP
	8	XRY	FP
	9	DECAY	FP
	10	UTMX	FP
	11	UTMY	FP
6	I - J	NUMSQ	I
	J+1 - 2*J	TYPE	I
	2*J+1 - 3*J	Q	FP
	3*J+1 - 4*J	DX	FP
	4*J+1 - 5*J	DY	FP
	5*J+1 - 6*J	H	FP
	6*J+1 - 7*J	HS	FP
	7*J+1 - 8*J	TS	FP
	8*J+1 - 9*J	VOL	FP
	9*J+1 - 10*J	DTH	FP
	10*J+1 - 12*J	RDS	FP
	11*J+1 - 12*J	NS	I
	12*J+1 - 12*J	VS	FP
	22*J+1 - 32*J	FREQ	FP
	32*J+1 - 33*J	JFLG	I
7**	1	THETA	FP
	2	UBAR	FP
	3	HM	FP
	4	TA	FP
	5	DPDZ	FP
	6	ISTBLE	FP

*The value of J is dependent upon the maximum number of sources that the program will accept. This value is currently 300, but can be altered by the procedures outlined under Card Group 2 in Section 3.2.3.a.

**Logical records 7 and 8 are repeated on the output tape for each meteorological observation from 1 to NHOURS. Logical record 8 occurs NSOURC times (one for each source) after each occurrence of logical record 7. Also, if the parameter NDAYS is greater than "1", the above group of logical records is written to the tape NDAYS times.

TABLE 3-6 (Continued)

Tape Logical Record	Word* Number	Parameter Name	Integer (I)/ Floating Point (FP)
7** (Cont.)	7	P	
	8	SIGEPU	FP
	9	SIGAPU	FP
	10	SIGEPL	FP
	11	SIGAPL	FP
	12	ALPHA	FP
	13	HOUR	FP
	14 - J+13	NUMSQB	FP
	J+14 - 2*J+13	QB	FP
	2*J+14 - 3*J+13	TSB	FP
	3*J+14 - 4*J+13	VOLB	FP
8**	1 - NXPNTS* NYPNTS+ NXWYPT	CON	FP

*The value of J is dependent upon the maximum number of sources that the program will accept. This value is currently 300, but can be altered by the procedures outlined under Card Group 2 in Section 3.2.3.a.

**Logical records 7 and 8 are repeated on the output tape for each meteorological observation from 1 to NHOURS. Logical record 8 occurs NSOURC times (one for each source) after each occurrence of logical record 7. Also, if the parameter NDAYS is greater than "1", the above group of logical records is written to the tape NDAYS times.

Logical records 7 and 8 are repeated on the output tape for each meteorological observation from 1 to NHOURS. Logical record 8 occurs NSOURC times (one for each source) after each occurrence of logical record 7. Also, if the parameter NDAYS is greater than "1", the above group of logical records (7 and 8 for NHOURS meteorological observations) are written to tape NDAYS times. The last output record is followed by two consecutive end of file marks. If the program reaches the end of reel marker on an output tape prior to the end of the output data, the program will write an end of file mark, an end of tape sentinel record and two more end of file marks and then go to the next specified output reel. The end of tape sentinel record consists of 14 UNIVAC 1110 words, with the first word of the record equal to an octal 541600000000 and all other words in the record equal to zero. See Section 3.2.2 for the correct tape assign cards.

3.2.5 Program Run Time, Page and Tape Output Estimates

This section gives approximations to the computer run time, tape output and page output for the SHORTZ program. Because of the variability of problem runs and input parameters, the equations in this section are meant only to give an approximation of the time, page or tape usage function.

a. Run Time. The total run time required for a problem run using the short-term (SHORTZ) program is given by

$$\text{Time (Seconds)} \cong \left[N_s \cdot \left(N_x \cdot N_y + N_{xy}\right) \cdot N_h \cdot N_d\right] \cdot f + \left.\left[\left(I + J + K\right) \cdot \left(N_x \cdot N_y + N_{xy}\right) \cdot N_h \cdot N_d\right] \cdot g\right\} \geq 120 \qquad (3\text{-}3)$$

where

N_s = the total number of input sources (card + tape) for which concentration is to be calculated

N_x = the total number of points in the grid system X-axis, NXPNTS

N_y = the total number of points in the grid system Y-axis, NYPNTS

N_{xy} = the total number of discrete (arbitrarily placed) points NXWYPT

N_h = the total number of input meteorological observations, NHOURS

N_d = the total number of days or cases, NDAYS

I = the number of sources read from an input tape

J = the number of sources written to an output tape

K = the summation of the total number of sources in each source combination printed. For example, if NGROUP were equal to "4" and three sources were combined for the first group, ten for the second, thirteen for the third and twenty-six for the fourth group, then K would be equal to 52

f = 2.1×10^{-3}

g = 2.2×10^{-3}

The constants f and g have been calculated from example runs on a UNIVAC 1108 computer. If the values of f and g given here are not accurate for your runs, recalculate and replace them with more representative values.

b. Page Output. The total number of pages of output from the SHORTZ program depends on the problem being run and is given by:

$$\text{Pages} \cong \underline{A} + \underline{B} + \underline{C} \qquad (3\text{-}4)$$

where*

$$\underline{A} = \left(I + \left\{ \left[\frac{N_x}{9} \right] \cdot \left[\frac{N_y}{38} \right] + \left[\frac{N_{xy}}{138} \right] \right\} \cdot J + \left[\frac{N_s}{44} \right] \cdot K + \left[\frac{N_h \cdot N_d}{N \cdot 40} \right] \cdot L \cdot M \right) \qquad (3\text{-}5)$$

$$I = \begin{cases} 1 & ; \text{ if ISW(6) = "1' or "3"} \\ 0 & ; \text{ if ISW(6) = "0" or "2"} \end{cases}$$

$$J = \begin{cases} 1 & ; \text{ if ISW(7)} > \text{"0"} \\ 0 & ; \text{ if ISW(7) = "0"} \end{cases}$$

$$K = \begin{cases} 1 & ; \text{ if ISW(6) = "2" or "3"} \\ 0 & ; \text{ if ISW(6) = "0" or "1"} \end{cases}$$

$$L = \begin{cases} 1 & ; \text{ if ISW(8)} > \text{"0"} \\ 0 & ; \text{ if ISW(8) = "0"} \end{cases}$$

N = ISW(1)

M = total number of input sources that have the parameter JFLG set equal to "1". If there are none, M = 1.

N_s = total number of sources input to the program

---

*The [ ] symbols indicate to round up to the next largest integer if there is any fractional part.

$$\underline{B} \cong I \cdot N_c \cdot \left(\left[\frac{N_x}{9} \right] \cdot \left[\frac{N_y}{43} \right] + \left[\frac{N_{xy}}{129} \right] \right) \tag{3-6}$$

$$I = \ell_1 + \ell_2 + \ell_3 + \ell_4$$

$$\ell_1 = \begin{cases} \dfrac{N_h \cdot N_d}{ISW(1)} & ; \text{ if ISW(2) > "0" and ISW(11) = "0"} \\ \dfrac{N_h}{ISW(1)} & ; \text{ if ISW(2) > "0" and ISW(11) > "0"} \\ 0 & ; \text{ if ISW(2) = "0"} \end{cases}$$

$$\ell_2 = \begin{cases} 0 & ; \text{ if ISW(3) = "0"} \\ \dfrac{N_h}{ISW(3)} & ; \text{ if ISW(3) > "0" and ISW(11) > "0"} \\ \dfrac{N_h \cdot N_d}{ISW(3)} & ; \text{ if ISW(3) > "0" and ISW(11) = "0"} \end{cases}$$

$$\ell_3 = \begin{cases} 0 & ; \text{ if ISW(4) = "0"} \\ \dfrac{N_h}{ISW(4)} & ; \text{ if ISW(4) > "0" and ISW(11) > "0"} \\ \dfrac{N_h \cdot N_d}{ISW(4)} & ; \text{ if ISW(4) > "0" and ISW(11) = "0"} \end{cases}$$

$$\ell_4 = \begin{cases} 0 & ; \text{ if ISW(5) = "0"} \\ \dfrac{N_h}{\text{ISW(5)}} & ; \text{ if ISW(5) > "0" and ISW(11) > "0"} \\ \dfrac{N_h \cdot N_d}{\text{ISW(5)}} & ; \text{ if ISW(5) > "0" and ISW(11) = "0"} \end{cases}$$

N_c = total number of combined source concentration tables being printed (NGROUP).

N_x = NXPNTS

N_y = NYPNTS

N_{xy} = NXWYPT

N_h = NHOURS

N_d = NDAYS

$C \cong$ the number of pages expected from the system plus other processing within the job

The above equations may not cover every option in the SHORTZ program and, if the system the user is using aborts runs that max-page, be generous with the page approximation.

c. Tape Output. The total amount of tape used by a problem run depends on the number of sources, the quantity of meteorological data and the size of the receptor arrays. This section provides the user with an approximation to the tape length used in feet.

The total number of computer words output to tape is given by

$$\text{Words} = \Big\{54 + N_x + N_y + 3 \cdot N_{xy} + N_x \cdot N_y + 33 \cdot I + N_d \cdot \Big(N_h \cdot \big((4 \cdot I + 13) + N_s \cdot (N_x \cdot N_y + N_{xy})\big)\Big)\Big\} \qquad (3\text{-}7)$$

where

N_x = NXPNTS

N_y = NYPNTS

N_{xy} = NXWYPT

N_d = NDAYS

N_h = NHOURS

N_s = the total number of card and/or tape output sources

I = 300 or the maximum number of sources possible, see Section 3.2.3.a, Card Group 2

The user can approximate the length of tape required by

$$\text{Length (feet)} \cong \left(\left(\frac{\text{Words} \cdot 36}{B_y \cdot D}\right) + 0.75 \cdot \left(\frac{\text{Words}}{2000}\right) + 6.0\right) \Big/ 12.0 \qquad (3\text{-}8)$$

where

B = the number of bits per computer word. UNIVAC 1110 is 36.

D = the tape recording density chosen by the user or required by the I/O device, 200, 556, 800 or 1600 bpi

B_y = "6" for 7-track tape or "8" for 9-track tape

The values of 0.75 and 6.0 inches assume that the interrecord gap is 0.75 and the end-of-file is 6 inches.

3.2.6 Program Diagnostic Messages

The diagnostic messages produced by the SHORTZ program are primarily associated with data and processing errors within the program and should not be confused with those produced by the computer system on which the SHORTZ program is run. WARNING messages could indicate data errors and should be examined thoroughly when they occur. A list of the messages are given in Table 3-7 with the probable cause of the respective message.

TABLE 3-7

SHORTZ WARNING AND ERROR MESSAGES

1. ***WARNING - SOURCE n TEMP. LESS THAN AMBIENT, PROGRAM USES AMBIENT***
   The stack gas exit temperature cannot be less than the ambient air temperature. The program sets the stack gas exit temperature equal to the ambient air temperature resulting in no plume rise for source n.

2. **WARNING Z > HM, SOURCE n, HOUR i, X = xxx.x, Y = yyy.y
   The terrain elevation exceeds the mixing layer elevation for source n, hour i at the X,Y coordinate shown.

3. **TOO MANY MESSAGES PROG. STOPS PRINTING THEM
   The program stops printing warning message 2 above after 50 of these messages are printed.

4. **ERROR, SIGAPU OR SIGEPU IS ZERO, CORRECT AND RERUN
   Default values for SIGAPU and SIGEPU are not provided if the parameter ISTBLE (stability category) is not punched or if the parameter ISW(16) equals "1". Correct the meteorological data and rerun.

5. ***ERROR, SIGAPL OR SIGEPL IS ZERO, CORRECT AND RERUN
   Default values for SIGAPL and SIGEPL are not provided if the parameter ISTBLE (stability category) is not punched or if the parameter ISW(16) equals "1". Correct the meteorological data and rerun.

6. ***ERROR, UBAR INPUT AS ZERO. PROG. STOPS
   A wind speed of zero is incorrect. Recheck your meteorological

TABLE 3-7 (Continued)

6. (Cont.)

data for format or key punch errors.

7. ***ERROR, HM INPUT AS ZERO, CORRECT AND RERUN

No default is provided for the mixing layer depth. Correct and rerun.

8. ***ERROR, TA INPUT AS ZERO, CORRECT AND RERUN

No default is provided for the ambient air temperature. Correct and rerun.

9. ***WARNING, P INPUT AS ZERO, PROG. USES ZERO AND CONTINUES

Default values for P are not provided if the parameter ISTBLE (stability category) is not punched. The surface wind speed has been used for all calculations associated with the respective meteorological observation.

10. ERROR, ATTEMPT TO MODIFY SOURCE n, BUT SOURCE NOT FOUND

A source input card with DISP > 0 and source number n has been read, but the program could not find the corresponding input tape source.

11. ***ERROR, VARIABLE Q's READ FOR SOURCE n, BUT SOURCE NOT IN INVENTORY, SEE CARD GROUP 11A

A variable emission rate card has been read after a meteorological input observation, but the source number (n) on the card does not match any of those in the source inventory.

12. ***ERROR, VARIABLE Q's READ FOR SOURCE n, BUT JFLG ON SOURCE CARD WAS READ

A variable emission rate card has been read after a meteorological

TABLE 3-7 (Continued)

12. (Cont.)
input observation, but the corresponding source in the inventory has not specified variable emission rates (JFLG=1)

13. ***ERROR, VARIABLE Q's READ FOR SOURCE n, BUT NO CHANGES INDICATED FOR SOURCE
A variable emission rate card has been read after a meteorological input observation for an input tape source, but DISP for the source does not indicate the emission rates are to be changed.

14. ***ERROR, JFLG is NON-ZERO FOR SOURCE n, BUT NO VARIABLE Q's FOUND
The source input card for source n had JFLG = "1", but a variable emission rate card (Card Group 11a) was not found in the input deck. Check the variable emission rate cards after each meteorological input observation card.

15. ***ERROR, NEW Q FOR SOURCE n READ, BUT CANNOT FIND OLD VARIABLE Q's
A source card has been read that indicates the user wishes to update the old emission rates (DISP=1). However, a flag is set that indicates the old emission rates were variable and cannot be found. Repunch the entire source card (Card group 9a) for this source with the new Q and DISP equal to zero. The program will delete the old source parameters and use the new source parameters to recalculate the concentrations for the source.

16. ***ERROR, SIGEPU OR SIGEPL IS LESS THAN OR EQUAL TO ZERO
Default values for SIGEPU and SIDEPL are not provided if the parameter ISTBLE (stability category) is not punched or if the parameter ISW(16) equals "1".

17. ***ERROR. SIGAPU OR SIGAPL IS LESS THAN OR EQUAL TO ZERO
Default values for SIGAPU and SIGAPL are not provided if the parameter ISTBLE (stability category) is not punched or if the parameter ISW(16) equals "1".

TABLE 3-7 (Continued)

18. ***READ ERROR ON UNIT n AT RECORD i
The program has encountered an unrecoverable tape I/O error on unit n at record i. Check your accounting page or the system log device for system messages that may specify the error.

19. ***END OF DATA ON UNIT n, i RECORDS READ
This message indicates a normal completion of the input tape data.

20. ***END OF FILE ON UNIT n, i RECORDS READ
This message indicates the program has successfully read and processed file n of the input tape data.

21. ***WARNING - MORE INPUT REELS THAN UNITS ASSIGNED, PROG. GOING TO FIRST UNIT ASSIGNED
The user has specified more input tapes (NINTP) than logical unit numbers given in NINFL. When the program has finished processing the tape on the last logical unit specified in NINFL, the program will go to the first logical unit specified in NINFL and expect the next sequential input tape reel on this unit.

22. ***WRITE ERROR ON UNIT n, at RECORD i
The program has encountered an unrecoverable tape I/O error on unit n at record i. Check your accounting page or the system log device for system messages that may specify the error.

23. **NTRAN ERROR*
An error has occurred has been detected by the UNIVAC NTRAN I/O routines. Check the Univac publication UP-7876 (FORTRAN V LIBRARY) for the cause of the error.

TABLE 3-7 (Continued)

24. ***WARNING - MORE OUTPUT REELS THAN UNITS ASSIGNED, PROG. GOING TO FIRST UNIT ASSIGNED

The user has specified more output tapes (NOTTP) than logical unit numbers given in NOTFL. When the program has finished processing the tape on the last logical unit specified in NOTFL, the program will go to the first logical unit specified in NOTFL and expect the next sequential output tape reel on this unit.

25. ***END OF OUTPUT REEL ON UNIT n RECORDS i THROUGH j WRITTEN

The program has encountered the end of reel marker on the tape on unit n. The program backs the tape 1 or 2 records, writes an end of file mark, an end of tape sentinel record and two more end of file marks. This tape is unloaded and the program goes to the next sequential output tape and rewrites any records that were backed over on the previous reel.

26. ***END OF OUTPUT DATA ON UNIT n RECORDS i THROUGH j WRITTEN, xxx.x FEET OF TAPE USED

The program has successfully written the output data to the last output tape. The program prints the amount of tape used in feet, assuming the tape is 9-track and written at 800 bpi.

27. ***WARNING - NOT ENOUGH ROOM ON REEL ON UNIT n, PROG STARTS FIRST OUTPUT REC. ON NEXT REEL

There was not enough room on the first reel to accommodate a complete record and the end of tape sentinel record information. The program goes to the next sequential output tape to start the tape output.

28. @ASG,T nnnnnnnnnnnn.,F/ii/POS/ii

@USE 12,nnnnnnnnnnnn.

MASS STORAGE CSF$ REQUEST REJECTED, STATUS=XXXXXXXXXXXX, TRIED M TIMES

TABLE 3-7 (Continued)

28. (Continued)

The program has attempted to assign mass storage unit 12 and has failed. Check the FAC status bits to determine the cause of the error.

29. **WARNING - COMPLEX TERRAIN SWITCH SET WITH DEPOSITION (NS), COMPLEX TERRAIN IGNORED

The user has attempted to calculate concentration with deposition occurring while using terrain elevation data. The SHORTZ program has discarded the terrain data in all calculations.

SECTION 4

USER'S INSTRUCTIONS FOR THE LONG-TERM (LONGZ) MODEL PROGRAM

4.1 SUMMARY OF PROGRAM OPTIONS, DATA REQUIREMENTS AND OUTPUT

4.1.1 Summary of LONGZ Program Options

The program options of the long-term computer program LONGZ consist of three general categories:

- Meteorological data input options
- Dispersion-model options
- Output options

Each category is discussed separately below.

a. Meteorological Data Input Options. Table 4-1 lists the meteorological data input options for the LONGZ computer program. All meteorological data may be input by card deck or by a previously generated tape inventory (see Section 4.1.1.c below). LONGZ accepts STAR summaries with six Pasquill stability categories (A through F) or five Pasquill stability categories (A through E with the E and F categories combined). Alternately, LONGZ accepts seasonal or annual summaries of the joint frequency of occurrence of wind-speed and wind-direction categories, subdivided into four time-of-day categories (night, morning, afternoon and evening). Site-specific mixing depths, vertical potential temperature gradients and ambient air temperatures are LONGZ input requirements rather than options. Although the program contains default values for the wind-profile exponents and vertical turbulent intensities, the user may also enter site-specific values of these parameters. Suggested procedures for developing these inputs are given in Section 2.1.1.2. The remaining meteorological data input options listed in Table 4-1 are identical to

TABLE 4-1

METEOROLOGICAL DATA INPUT OPTIONS FOR LONGZ

Input of all meteorological data by card deck or by previously generated tape inventory
STAR summaries with five or six Pasquill stability categories
Site-specific mixing depths
Site-specific ambient air temperatures
Site-specific wind-profile exponents
Site-specific vertical potential temperature gradients
Site-specific vertical turbulent intensities (different values may be entered for stacks and for building and area sources)
Entrainment coefficients other than the Briggs (1972) coefficients
Wind system measurement height other than 6.1 meters

TABLE 4-2

DISPERSION-MODEL OPTIONS FOR LONGZ

Inclusion of the effects of gravitational settling and dry deposition in concentration calculations
Inclusion of terrain effects
Cartesian or polar receptor system
Discrete receptors (Cartesian or polar system)
Stack, building and area sources
Pollutant emission rates held constant or varied by season, wind speed and stability
Time-dependent exponential decay of pollutants
Time periods for which concentration calculations are to be made (seasonal and/or annual)

the SHORTZ meteorological data input options discussed in Section 3.1.1.a.

b. Dispersion-Model Options. Table 4-2 lists the dispersion-model options for the LONGZ computer program. In general, these options correspond to the SHORTZ dispersion-model options discussed in Section 3.1.1.b. Pollutant emission rates may be held constant or varied by season or by wind speed and stability in LONGZ calculations. The program uses seasonal STAR summaries to calculate seasonal and/or annual concentration values or an annual STAR summary to calculate annual concentration values. Additionally, monthly STAR summaries may be used to calculate monthly concentrations.

c. Output Options. Table 4-3 lists the LONGZ program output options. A more detailed discussion of the LONGZ output information is given in Section 4.1.3.

The LONGZ program has the capability to generate a master tape inventory containing all meteorological and source inputs and the results of all concentration calculations. This tape can then be used as input to future update runs. For example, assume that the user wishes to add a new source and modify an existing source at a previously modeled industrial source complex. Concentration calculations are made for these sources alone and the results of these calculations in combination with select sources from the original tape inventory are used to generate an updated inventory. That is, it is not necessary to repeat the concentration calculations for the unaffected sources in the industrial source complex in order to obtain an updated estimate of the concentration values for the combined emissions. The optional master tape inventory is discussed in detail in Section 4.2.4.b.

The LONGZ user may elect to print one or more of the following tables:

TABLE 4-3

LONGZ OUTPUT OPTIONS

Master tape inventory of meteorological and source inputs and the results of the concentration calculations

Printout of program control parameters, meteorological data and receptor data

Printout of tables of source input data

Printout of seasonal and/or annual average concentrations calculated at each receptor for each source or for the combined emissions from a select group of all sources

- The program control parameters, meteorological input data and receptor data

- The source input data

- The seasonal and/or annual average concentrations calculated at each receptor for each source or for the combined emissions from select source groups or for all sources

4.1.2 Data Input Requirements

This section provides a description of all input data parameters required by the LONGZ program. The user should note that some input parameters are not read or are ignored by the program, depending on the values assigned to the control parameters (options) by the user.

a. Program Control Parameter Data. These data contain parameters which provide user-control over all program options.

Parameter Name	
ISW(1)	Master Source/Concentration Magnetic Tape Input Option -- Specifies whether or not tape input is being used. A value of "0" indicates tape input is not being used. A value of "1" indicates tape input is being used and the tape data are read from the logical units specified by the array NINFL below. A value of "2" also indicates tape input in the same manner as a value of "1". However, if "2" is specified the program assumes that new meteorological data are to be read from data card to replace that taken from the tape. In this case, all concentration arrays for each source are recalculated. The default for this parameter is "0".

Parameter Name	
(ISW(2)	Master Source/Concentration Magnetic Tape Output Option -- Specifies whether or not tape output is being used. A value of "0" indicates tape output is not being used. A value of "1" indicates tape output is being used and the output is written to the tape or tapes specified by the logical units given by the array NOTFL below. A value of "2" indicates tape output in the same manner as a value of "1"; however, the program additionally prints a table of the output source inventory. The default for this parameter is "0".
ISW(3)	Seasonal Concentration Print Output Option -- Specifies whether or not seasonal concentrations are to be calculated and printed. A value of "0" specifies that seasonal concentrations are not printed. A value of "1" indicates seasonal concentration tables are to be printed. The default for this parameter is "0".
ISW(4)	Annual Concentration Print Output Option -- Specifies whether or not annual concentrations are to be calculated and printed. A value of "0" specifies that annual concentration tables are not printed. A value of "1" indicates annual concentration tables are to be printed. The default for this parameter is "0".
ISW(5)	Print Input Data Option -- Specifies which input data except for source data are to be printed. A value of "0" indicates program control and meteorological data are not printed. A value of "1" indicates program control and meteorological data are to be printed. The default for this parameter is "0".

Parameter Name	
ISW(6)	Print Input Card Sources -- Specifies whether or not the input data card sources are to be printed. A value of "0" indicates the input data card sources are not to be printed. A value of "1" indicates the input data card sources are to be printed. The default for this parameter is "0".
ISW(7)	Print Input Tape Sources -- Specifies whether or not the input tape sources are to be printed. A value of "0" indicates the input tape sources are not to be printed. A value of "1" indicates the input tape sources are to be printed. The default for this parameter is "0".
ISW(8)	Receptor Terrain Elevation Option -- Specifies whether the user desired to input the terrain elevations for each receptor point or to use the program as a flat terrain model. A value of "0" indicates terrain elevations are not to be input and a value of "1" indicates terrain elevations for each receptor point are to be input. Note that terrain elevations cannot be used when calculating concentration with deposition occuring (see Section 2.4.4). The default for this parameter is no terrain or "0".
ISW(9)	Wind Speed Power Law Option -- If a value of "0" is used, the wind speed power law is based on emission elevation above the airport (weather station) elevation. If the emission elevation is below the airport (weather station) elevation, no power law is used. If a value of "1" is used, the wind speed power law is based on the emission height above terrain and a power law is always used. If this parameter is not punched, the program will default to a value of "0".

Parameter Name	
ISW(10)	Print Output Unit Option -- This option is provided to enable the user to print the program output on a unit other than print unit "6". Otherwise, print output goes to the specified unit. Also, if this value is punched and not equal to "6" or "56", two end-of-file marks are written at the end of the print file and the tape is rewound.
ISW(11)	Optional Format for Joint Frequency of Occurrence -- This parameter is a switch used to inform the program whether it is to use a default format to read the joint frequency of occurrence of speed and direction (FREQ) or to input the format via data card. If this option is not punched or is "0", the program uses the default format given under FMT below. If this option is set to a value of "1", the array FMT below is read by the program.
ISW(12)	Optional Format for Source Card Input Data -- This parameter is a switch used to inform the program whether it is to use a default format to read the card input source data or to input the format via data card. If this option is not punched or is "0", the program uses the default format given under SFMT below. If this option is set to a value of "1", the array SFMT below is read by the program.
ISW(13)	Receptor Reference Grid System Option -- Specifies whether a right-handed rectangular Cartesian coordinate system or a polar system is to be input to the program to form the receptor reference grid system. A value of "0" indicates a Cartesian reference grid system is being input and a value of "1" indicates a polar reference grid system is

Parameter Name	
ISW(13) (Cont.)	being input. If this parameter is not punched, the program will default to a value of "0".
ISW(14)	Discrete Receptor Option -- Specifies whether a right-handed rectangular Cartesian reference system or polar reference system is used to reference the input discrete receptor points. A value of "0" indicates that the Cartesian reference system is used and a value of "1" indicates a polar reference system is used. If this parameter is not punched, the program will default to a value of "0".
ISW(15)	Source Receptor Option -- Specifies whether a right-handed rectangular Cartesian reference system or polar reference system is used to reference the input source coordinates. A value of "0" indicates that the Cartesian reference system is used and a value of "1" indicates a polar reference system is used. If this parameter is not punched, the program will default to a value of "0".
ISW(16)	Turbulent Intensities Option -- This option allows the user to enter different turbulent intensities for stacks and for building and area sources. If this parameter is not punched or is "0", the program uses the same turbulent intensities (SIGEPU) for all source types. If ISW(16) equals "1", different turbulent intensities are entered for stacks (SIGEPU) and for area and building sources (SIGEPL). No default turbulent intensities are provided if ISW(16) equals "1". The default value for the parameter ISW(16) is "0", or the same turbulent intensities for all source types.

Parameter Name	
ISW(17)	Rural/Urban Model Option -- If the Turbulent Intensities Option is not used (*i.e.*, if ISW(16) equals "0"), this option directs the program to use the Cramer, *et al*. (1975) rural or urban turbulent intensities corresponding to the Pasquill stability categories as default values for all source types. The program uses the rural turbulent intensities as default values if ISW(17) equals "0" and the urban turbulent intensities as default values if ISW(17) equals "1". The default value for the parameter ISW(17) is "0". It should be emphasized that the program will not use default turbulent intensities if the parameter ISW(16) above equals "1".
ISW(18) - ISW(20)	Reserved for future options.
NSOURC	Number of Data Card Input Sources -- This parameter specifies the number of input card image sources. This includes card images that specify a new source being entered and card images that specify modifications or deletions to sources input from tape. If this value is not punched or is "0", the program assumes all sources are input from tape. The maximum number of sources that can be processed is 14000 and 14000 is the largest source identification number (NUMSQ1) possible.
NGROUP	Number of Source Combination Groups -- This parameter specifies the number of different source combinations for which print output is desired. A source combination consists of one or more of all the input sources and is the summed output of those selected sources. The maximum value for this parameter is 1000. If this parameter is

Parameter Name

NGROUP (Cont.)

not punched or is "0", the program assumes that no concentration output tables are to be produced. Also, if this parameter is not punched or is "0", the associated parameter arrays NSOGRP and IDSOR below are not read by the program and can be ignored.

NXPNTS

X-Axis/Range Receptor Grid Size -- This parameter specifies the number of east-west receptor grid locations for the Cartesian coordinate system X-axis, or the number of receptor grid ranges (rings) in the polar coordinate system, depending on which receptor grid system is chosen by the user under parameter ISW(13). This is the number of X-axis points to be input or the number of X-axis points to be automatically generated by the program. A value of "0" (not punched) directs the program to assume there is no regular receptor grid being used. The maximum value of this parameter is related to other parameter values and is given by the equation

$$E \geq \left[N_x+N_y+2N_{xy}\right] + 6 \cdot \left[N_x \cdot N_y+N_{xy}\right] \qquad (4\text{-}1)$$

where

E = the total amount of program data storage in BLANK COMMON. The design size is 12000, but can be increased by a simple program modification given in Section 4.2.3.a under Card Group 2

N_x = number of points in the input X-axis of the receptor grid system (NXPNTS)

Parameter Name

N_y = number of points in the input Y-axis of the receptor grid system (NYPNTS)

NXPNTS (Cont.)

N_{xy} = number of discrete (arbitrarily placed) input receptors (NXWYPT)

This parameter is ignored by the program if tape input is being used.

NYPNTS

Y-Axis/Azimuth Receptor Grid Size -- This parameter specifies the number of north-south receptor grid locations for the Cartesian coordinate system Y-axis, or the number of Y-axis azimuth bearings from the origin in the polar coordinate system, depending on which receptor grid system is chosen by the user under parameter ISW(13). This is the number of Y-axis points to be input or the number of Y-axis points to be automatically generated by the program. If the parameter NXPNTS is set non-zero, the parameter NYPNTS must also be non-zero. The maximum value of this parameter is given by the equation under NXPNTS above. The parameter NYPNTS is ignored by the program if tape input is being used.

NXWYPT

Number of Discrete (Arbitrarily Placed) Receptors -- This parameter specifies the total number of discrete receptor points to be input to the program. A value of "0" (not punched) directs the program to assume no discrete receptors are being used. Also, the maximum value of this parameter is ignored by the program if input tape is being used. ISW(14) specifies whether these points are in Cartesian or polar coordinates.

Parameter Name	
NSEASN	Number of Seasons -- This parameter specifies the number of seasons or months in the input meteorological data. A value of "0" (not punched) defaults to "1". Also, if annual meteorological data are being used, a value of "1" must be specified. The maximum value of this parameter is "4". This parameter is ignored by the program if an input tape is being used.
NSPEED	Number of Wind Speed Categories — This parameter specifies the number of wind speed categories in the input joint frequency of occurrence of wind speed and direction (FREQ). A value of "0" (not punched) causes the program to default to "6" (maximum). This parameter is ignored by the program if an input tape is being used.
NSTBLE	Number of Pasquill Stability Categories -- This parameter specifies the number of Pasquill stability categories in the input joint frequency of occurrence of wind speed and direction (FREQ). A value of "0" (not punched) causes the program to default to "5" (maximum=6). This parameter is ignored by the program if an input tape is being used.
NSCTOR	Number of Wind Direction Sector Categories -- This parameter specifies the number of wind direction sector categories in the input joint frequency of occurrence of wind speed and direction (FREQ). A value of "0" (not punched) causes the program to assume the standard "16" (maximum) sectors are to be used. This parameter is ignored by the program if an input tape is being used.

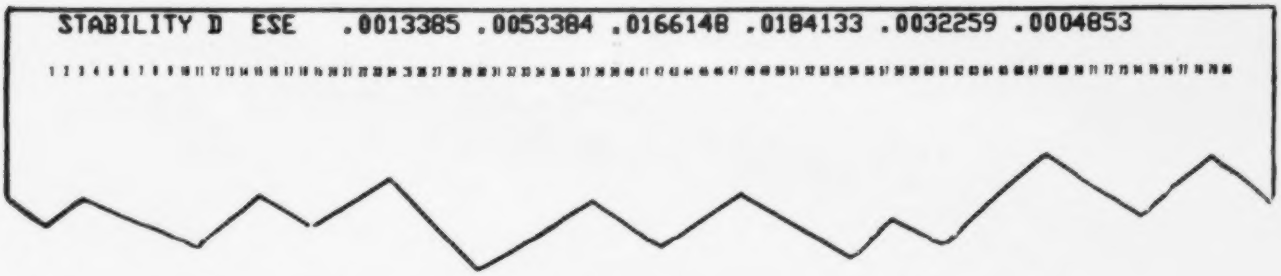
Parameter Name	
NSORX	Total Number of Tape Output Sources - This parameter is used only when both input and output tapes are used and specifies the total number of non-deleted sources in the output tape inventory at the completion of the run. If not punched or a value of "0" is used, the program uses NSOURC or NSOURC plus the number of sources on the input tape. This parameter must be punched if both input and output tapes are used and NSOURC is greater than zero, unless the card sources are only additions to the inventory.
NSTOP	Last Source Option -- This parameter specifies the source identification number (NUMSZ1) of the last source to be read from an input tape. If not punched or a value of "0" is punched, the program will read the entire input tape.
NINTP	Number of Input Tapes - This parameter gives the number of input magnetic tapes when the ISW(1) > "0" option is selected. If this parameter is not punched or is set to a value of "0", the program defaults to a value of "1". The maximum for this parameter is "3".
NOTTP	Number of Output Tapes -- This parameter gives the number of output magnetic tapes the user has provided when the ISW(2) > "0" option is selected. If this parameter is not punched or is set to a value of "0", the program defaults to a value of "1". The maximum for this parameter is "3".
NINFL	Input Tape Logical Unit Numbers -- This parameter is an array of a maximum of three logical unit numbers used

Parameter Name	
NINFL	for magnetic tape input. If the values in this array are not punched or are set equal to "0", the program defaults the values to "2", "0" and "0", respectively. The user must equate the logical unit numbers specified here with the external file name assigned to the tape as shown in Section 4.2.2.
NOTFL	Output Tape Logical Unit Numbers -- This parameter is an array of a maximum of three logical unit numbers used for magnetic tape output. If the values in this array are not punched or are set to values of "0", the program defaults the values to "3", "0" and "0", respectively. The user must equate the logical unit numbers specified here with the external file name assigned to the tape as shown in Section 4.2.2.
NSOGRP	Number of Sources Defining Combined Source Groups -- This parameter is not read by the program if the parameter NGROUP above is zero or not punched. Otherwise, this parameter is an array of NGROUP values where each value gives the number of source identification numbers used to define a source combination. The source identification number is that number assigned to each source by the user under the source input parameter NUMSQ1 below. An example and a more detailed discussion of the use of this parameter is given under IDSOR below. A maximum of 1000 values are provided for this array.
IDSOR	Combined Source Group Defining Sources -- This parameter is not read by the program if the parameter NGROUP above

Parameter Name	
IDSOR (Cont.)	is zero or not punched. Otherwise, this parameter is an array of source identification numbers that define each combined source group to be output. The values punched into the array NSOGRP above indicate how many source identification numbers are punched into this array successively for each combined source output. The source identification numbers can be punched in two ways. The first is to punch a positive value directing the program to include that specific source in the combined output. The second is to punch a negative value. When a negative value is punched, the program includes all sources with identification numbers less than or equal to it in absolute value. Also, if the negative value is preceded by a positive value in the same defining group, that source defines the first of the sources to be included with those defined by the negative number, but no sources with a lesser source identification number are included. For example, assume NGROUP above is set equal to 4 and the array NSOGRP contains the values 3, 2, 1, 0. Also, assume the entire set of input sources is defined by the source identification numbers 5, 72, 123, 223, 901, 902, 1201, 1202, 1205, 1206 and 1207. To this point we have a total of 11 input sources and we desire to see 4 combinations of sources taken from these 11. Also, the array NSOGRP indicates that the first 3 values in the array IDSOR define the first source combination, the next 2 values (4th and 5th) in IDSOR define the second combination, the 6th value in IDSOR defines the third combination and the last combination has no defining (0) sources so the program assumes all 11 sources are used.

Parameter Name	
IDSOR (Cont.)	Similarly, let the array IDSOR be set equal to the values 5, 72, -223, 1201, -1207, -902. The program will first produce combined source output for sources 5, 72 and all sources up to and including 223. The second combined source output will include sources 1201 through 1207. The third will include sources numbers 5 through 902 and the last will include all sources input. Note that the source identification numbers in each defining group are in ascending order of absolute value. The maximum number of values that can be input to this array is 1000.
FMT	Optional Format for Joint Frequency of Occurrence -- This parameter is an array which is read by the program only if ISW(11) is set to a value of "1". The FMT is used to specify the format of the joint frequency of occurrence of wind speed and direction data (FREQ, $f_{i,j,k,\ell}$ in Table 2-7). The format punched, if used, must include leading and ending parentheses. If parameter FMT is omitted from the input deck, the program uses the default format "(6F10.0)". This default format specifies that there are 6 real values per card occupying 10 columns each, including the decimal point (period) and the first value is punched in columns one through ten. If the user has received the STAR data from an outside source, the deck must also be checked for the proper order as well as format and, if the order is not correct, the data must be repunched. The correct order of the STAR deck punched in a format not compatible with the default format for FMT is

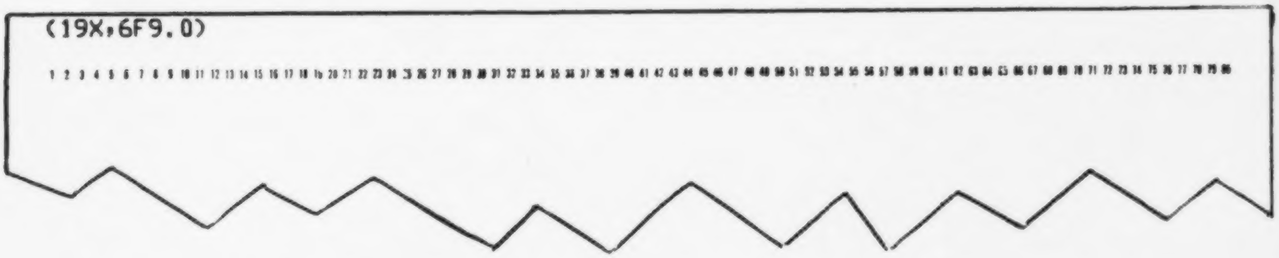
Parameter
Name



```
STABILITY D  ESE   .0013385 .0053384 .0166148 .0184133 .0032259 .0004853
```

FMT
(Cont.)

This example shows the stability and direction categories punched in columns 2 through 17 and the frequency of occurrence data occupying columns 20 through 73. To input these data the user would set ISW(11) equal to "1" and punch the format (FMT) as shown on the following example input data card



```
(19X,6F9.0)
```

This format directs the LONGZ program to skip the first 19 columns on each frequency of occurrence card read and to read six equally-spaced real values from the card. Each value occupies 9 columns including the decimal point (period). The first value begins in column 20. The program interprets the leading blank character of each value as zero.

SMFT

Optional Format for Source Data -- This parameter is an array which is read by the program only if ISW(12) is set to a value of "1". The array SFMT is used to specify the format used for the input card source data. The format punched, if used, must include leading and ending parentheses. If ISW(12) is not punched or is set to a value

Parameter Name	
SFMT (Cont.)	of "0", the parameter SFMT is omitted from the input deck and the program uses the default format "(I5,2I1,6F7.0,4F6.0, F5.0,I2)". This format is used to read the variables -- NUMSQ1, TYPE1, DISP, Q1(1), Q1(2), Q1(3), Q1(4), DX1, DY1, H1, HS1, TS1, VOL1, RDS1 and NVS1. These parameters are the primary source inputs and are defined under the source input data below.

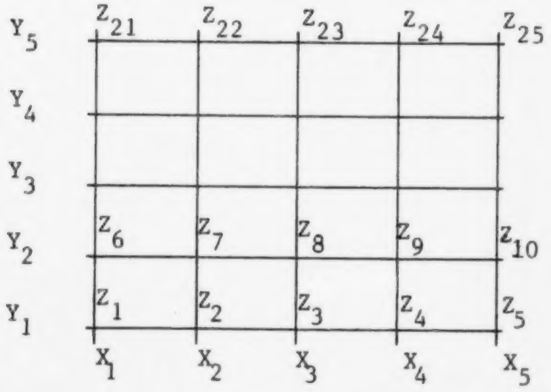
b. Receptor Data. These data consist of the (X,Y) or (range, azimuth) locations of all receptor points as well as the elevations of the receptors above mean sea level.

Parameter Name	
X	Receptor Grid System X-Axis or Range -- This parameter is read by the program only if the parameters NXPNTS and NYPNTS are non-zero and only if an input tape is not being used. This parameter is an array of values in ascending order that defines the X-axis or ranges (rings) (depending on ISW(13)) of the receptor grid system in meters. If only 2 values are input and the parameter NXPNTS is greater than 2, the program assumes the X-axis (range) is to be generated automatically and assumes the first value is the starting X coordinate and the second value is an increment used to generate the remaining NXPNTS evenly-spaced X coordinates. If all receptor points are being input, NXPNTS values must be punched. The origin of the grid system is defined by the user and can be anywhere.
Y	Receptor Grid System Y-Axis or Azimuth -- This parameter is read by the program only if the parameters NXPNTS and

Parameter Name	
Y (Cont.)	NYPNTS are non-zero and only if an input tape or data file is not being used. This parameter is an array of values in ascending order that defines the Y-axis or azimuth bearings measured clockwise from zero degrees (north) (depending on ISW(13)) of the receptor grid system in meters or degrees. If only 2 values are input (third value is zero) and the parameter NYPNTS is greater than 2, the program assumes the first value is the starting Y coordinate and the second value is the increment used to generate the remaining NYPNTS evenly-spaced (rectangular or angular) Y coordinates. If all receptor points are being input, NYPNTS values must be punched. If polar coordinates are being used, Y is measured clockwise from zero degrees (north).
X (Discrete)	Discrete (Arbitrarily Placed) Receptor X or Range -- This parameter is not read by the program if the parameter NXWYPT is zero or if the program is using an input tape. This parameter is an array defining all of the discrete receptor X points. The values are either east-west distances or radial distances in meters, depending on the type of reference system specified by ISW(14). NXWYPT points are read by the program. The origin of these points is the same as the origin of the regular (non-discrete) grid system if one is used. Otherwise, the origin is defined by the user and can be located anywhere.
Y (Discrete)	Discrete (Arbitrarily Placed) Receptor Y or Azimuth -- This parameter is not read by the program if the parameter NXWYPT is zero or if the program is using an input tape. This parameter is an array defining all of the discrete receptor Y points in meters or degrees. The values are either north-south distances or azimuth bearings

Parameter Name	
Y (Discrete) (Cont.)	(angular distances) measured clockwise from zero degrees (north), depending on the type of reference system specified by ISW(14). NXWYPT points are read by the program.
Z	Elevation of Grid System Receptors - This parameter is not read by the program if the parameter ISW(8) is zero or if an input tape is being used or if NXPNTS or NYPNTS equals zero. This parameter is an array specifying the terrain elevation in meters above mean sea level at each receptor of the Cartesian or polar grid system. There are NXPNTS · NYPNTS values read into this array. The program starts the input of values with the first Y coordinate specified and reads the elevations for each X coordinate at that Y in the same order as the X coordinates were input. A new data card is started for each successive Y value and the NXPNTS elevations for that Y are read. The program will expect NYPNTS groups of data cards with NXPNTS elevation values punched in each group. For example, assume we have a 5 by 5 Cartesian or polar receptor array:

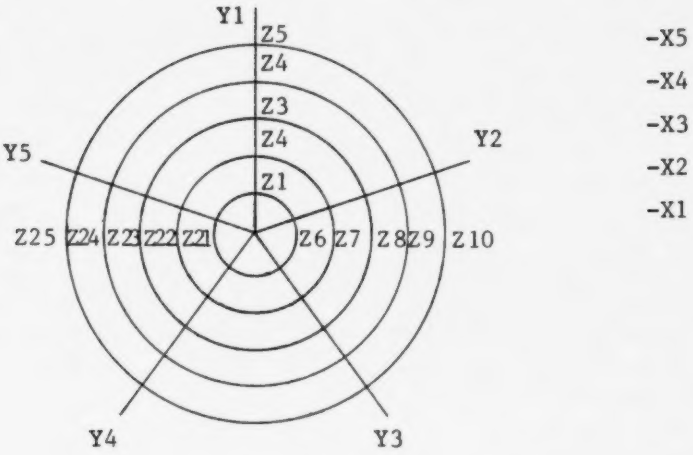
Rectangular



Parameter
Name

Z
(Cont.)

Polar



The values Z_1 through Z_5 are read from the first card group, the values Z_6 through Z_{10} from the second card group and Z_{21} through Z_{25} from the last card group.

Z
(Discrete)

Elevation of the Discrete (Arbitrarily Placed) Receptors -- This parameter is not read by the program if the parameter ISW(8) is zero or if the parameter NXWYPT equals zero. This parameter, which is an array specifying the terrain elevation in meters at each of the NXWYPT discrete receptors, is input in the same order as the discrete receptors.

c. Identification Labels and Model Constants. These data consist of parameters pertaining to heading and identification labels and program constants. These data except for TITLE are not read by the program if an input tape is being used.

Parameter Name	
TITLE	Page Heading Label -- This parameter is an array that allows up to 80 characters of title information to be printed as the first line of each output page.
LUNT	Concentration Units Label -- This parameter is an array used for the optional input of the concentration units label. There are a maximum of 24 characters provided for an optional output units label for concentration. This label is defaulted to "(micrograms/cubic meter)" for concentration if the parameter TK below is not punched or is "0".
LKNT	Source Units Label -- This parameter is a 12 character array provided for an optional source input units label. This label is defaulted to "(grams/second)" if the parameter TK below is not punched or is "0".
ROTATE	Wind Direction Correction Angle -- This parameter is used to correct for any difference between north as defined by the X, Y reference grid system and north as defined by the weather station at which the wind direction data were recorded. The value of ROTATE (degrees) is subtracted from each wind-direction sector angle (THETA). This parameter is positive if the positive Y axis of the reference grid system points to the right of north as defined by the weather station. Most weather stations record direction relative to true north and the center of most grid systems are relative to true north. However, some weather stations record direction relative to magnetic north and the ends of some UTM (Universal Transverse Mercator) zones are not oriented towards true north. The user is cautioned to

Parameter Name	
ROTATE (Cont.)	check the wind data as errors in the wind direction distribution will lead to erroneous program results.
TK	Model Units Conversion Factor -- This parameter is provided to give the user flexibility in the source input units used and the concentration output units desired. This parameter is a direct multiplier of the concentration equation. If this parameter is not punched or is set to a value of "0", the program defaults to "1 x 10^6" micrograms per gram. This default assumes the user desires concentration in micrograms per cubic meter and the input source units are grams per second. Also, if the default value for this parameter is selected, the program defaults the units labels in the arrays LUNT and LKNT above. If the user chooses to input this parameter for other units, he must also input the units labels in LUNT and LKNT above. This parameter corresponds to K in Equations (2-32), (2-37) and (2-42).
HA	Station Elevation -- This parameter gives the elevation of the airport or weather station in meters above mean sea level and is used only if terrain elevations are input for the receptor points.
UTMX	X-Origin of Polar Reference System -- This parameter gives the east-west Cartesian coordinate of the origin of the polar reference system and/or discrete polar coordinates. If this parameter is not punched or a value of "0" is used, all polar coordinates are relative to the point (0,0), and the polar coordinates are printed. However, if this parameter is set to a non-zero value, all polar coordinates are

Parameter Name	
UTMX (Cont.)	are relative to this Cartesian X coordinate and the program converts all discrete polar coordinates to their respective Cartesian coordinates for the calculation and print output of concentration tables.
UTMY	Y-Origin of Polar Reference System -- This parameter gives the north-south Cartesian coordinate of the origin of the polar reference system and/or discrete polar coordinates. If polar coordinates are not used, this parameter is ignored. If this parameter is not punched or a value of "0" is used, all polar coordinates are relative to zero and the polar coordinates are printed. However, if this parameter is set to a non-zero value, all polar coordinates are relative to this Cartesian Y coordinate and the program converts all discrete polar coordinates to their respective Cartesian coordinates for the calculation and print output of concentration tables.
ZR	Weather Station Wind Measurement Height -- This parameter is the height above ground level in meters at which the wind data were recorded. If this parameter is not punched or has a value of "0", the program defaults to "6.1" meters. This parameter corresponds to Z_R in Equation (2-13).
GAMM1	Adiabatic/Unstable Entrainment Coefficient -- This parameter, which is used in plume rise calculations, is the air entrainment coefficient for an adiabatic or unstable atmosphere. If this value is not punched or is "0", the program uses "0.6" as the default value. This parameter corresponds to γ_1 in Equation (2-3).

Parameter Name	
GAMMA2	Stable Entrainment Coefficient -- This parameter, which is used in the plume rise calculations, is the air entrainment coefficient for a stable atmosphere. If this value is not punched or is "0", the program uses "0.66" as the default value. This parameter corresponds to γ_2 in Equation (2-7).
G	Acceleration Due to Gravity -- This parameter, which is used in the plume rise calculations, is the acceleration due to gravity. If this parameter is not punched or has a value of "0", the program uses "9.8" meters per second squared as the default value.
DECAY	Decay Coefficient -- This parameter is the coefficient (seconds^{-1}) of time-dependent pollutant removal by physical or chemical processes (see Equation (2-12)). The default for this parameter is "0".

d. Meteorological Data. These data are the meteorological input parameters classified according to one or more of the categories of wind speed, Pasquill stability or time of day, wind direction and season or annual. These parameters are not read by the program if an input tape is being used, unless ISW(1) is set equal to a value of "2".

Parameter Name	
FREQ	Joint Frequency of Occurrence -- This parameter array consists of the seasonal or annual joint frequency of occurrence of wind-speed and wind-direction categories classified according to the Pasquill stability categories

Parameter Name	
FREQ (Cont.)	or four time-of-day categories ($f_{i,j,k,\ell}$ in Table 2-7). This parameter has no default and must be input in the correct order. The program begins by reading the joint frequency table for season 1 (winter) and stability category 1 (Pasquill A stability or night). The first data card contains the joint frequencies of wind speed categories 1 through 6 (1 through NSPEED) for the first wind direction category (north). The second data card contains the joint frequencies of wind speed categories 1 through 6 for the second wind direction category (north-northeast). The program continues in this manner until the joint frequencies of the last direction category (north-northwest) for stability category 1, season 1 have been read. The program then repeats this same read sequence for stability category 2 (Pasquill B stability or morning) and season 1. When all of the stability category values for season 1 have been read, the program repreats the read sequence for season 2, season 3, etc., until all of the joint frequency values have been read. There are a total of NSPEED*NSCTOR* NSTBLE*NSEASN values read in this data card group and a total of NSCTOR*NSTBLE*NSEASN data cards. If the total sum of the joint frequency of occurrence for any season (or annual) does not add up to 1, the program will automatically normalize the joint frequency distribution by dividing each joint frequency by the total sum. Also, the program assumes stability categories 1 through 6 are Pasquill stabilities A through F. Alternately, the program assumes that time-of-day category 1 is night, category 2 is morning, category 3 is afternoon and category 4 is night. Seasons 1 through 4

Parameter Name	
FREQ (Cont.)	are normally winter, spring, summer and fall. See the parameter FMT above for the format of these data.
TA	Average Ambient Air Temperature -- This parameter array consists of the average ambient air temperatures ($T_{a;k,\ell}$ in Table 2-7), classified according to season (or annual) and stability or time of day category, in degrees Kelvin. One data card is read for each season (1 to NSEASN) with the temperature values for stability categories 1 through NSTBLE punched across the card. When the program has completed reading these data cards, it will scan all of the values in the order of input and, if any value is not punched or is zero, the program will default to the last non-zero value of TA it encountered.
HM	Mixing Layer Depth -- This parameter array consists of the median mixing layers depth in meters ($H_{m;i,k,\ell}$ in Table 2-7), classified according to wind speed, stability or time of day, and season (or annual). The program begins reading the mixing layer depths for season 1. The program reads the mixing layer depth values for each wind speed category (1 to NSPEED) from each card. There are NSTBLE (1 through NSTBLE) cards read for each season. The program scans each value input in the order of input and, for each season, if a zero or non-punched value is found, the program defaults to the last non-zero value encountered within the values for that season.
DPDZ	Potential Temperature Gradient -- This parameter array consists of the vertical gradients of potential temperature

Parameter Name	
DPDZ (Cont.)	$\left(\left(\frac{\partial\theta}{\partial z}\right)_{i,k} \text{in Table 2-7}\right)$, classified according to wind speed and stability or time-of-day category in units of degrees Kelvin per meter. There are NSTBLE (1 through NSTBLE) data cards read with the values for wind speed categories 1 through NSPEED read from each card.
UBAR	Wind Speed -- This parameter array consists of the median wind speeds in meters per second ($\bar{u}\{z_R\}_i$ in Table 2-7) for the wind-speed categories used in the calculation of the joint frequency of occurrence of wind speed and direction. There are NSPEED values read from this card and if any value is not punched or is zero, the program defaults to the following set of values: 0.75, 2.5, 4.3, 6.8, 9.5 and 12.5 meters per second.
THETA	Wind Direction -- This parameter array consists of the median wind direction angles in degrees for the wind-direction categories used in the calculation of the joint frequency of occurrence of wind speed and direction. There are NSCTOR values read from 1 to 2 data cards and, if the first two values of this array are not punched or are zero, the program defaults to the following standard set of values: 0, 22.5, 45, 67.5, 90, ..., 336.5 degrees (N, NNE, NE, ..., NNW). The wind direction is that angle from which the wind is blowing, measured clockwise from zero degrees (north).
P	Wind Speed Power Law Exponent -- This parameter array consists of the wind speed power law exponents (p in Equation 2-13)) classified according to wind speed and

Parameter Name

stability or time-of-day category. There are NSPEED (1 through NSPEED) values read per data card for stability categories 1 through NSTBLE. If any value on any data card in this set is not punched or is zero, the program defaults to the value from the following set of values:

P (Cont.)

Pasquill Stability Category	Wind Speed Category Number					
	1	2	3	4	5	6
A	.10	.10	.10	.10	.10	.10
B	.15	.10	.10	.10	.10	.10
C	.20	.15	.10	.10	.10	.10
D	.25	.20	.15	.10	.10	.10
E	.30	.25	.20	.15	.10	.10
F	.40	.30	.20	.15	.10	.10

SIGEPU

Standard Deviation of the Wind Elevation Angle for Elevated Sources -- This parameter array gives the standard deviation of the wind elevation angle for stack sources (and building and area sources if ISW(16) equals "0") by wind speed and stability or time-of-day category. There are NSPEED values read (1 through NSPEED) per data card for stability categories 1 through NSTBLE. The units of SIGEPU are radians or degrees. If the value is greater than or equal to "1", the program assumes the units are degrees. If the option ISW(16) equals "1", the values of SIGEPU are used only for stack (TYPE1="0") sources and no default values are provided. Also, the values for building and

Parameter Name	
SIGEPU (Cont.)	area sources are read into the parameter SIGEPL below. If the option ISW(16) equals "0" the values of SIGEPU are used for both stack (TYPE1="0") sources and building (TYPE1 ="1") and area (TYPE1="2") sources. Default values are provided if any value of SIGEPU is "0" or not punched. The default value depends on the stability category (order of the data card) and ISW(17). If ISW(17) equals "0", the rural mode is assumed and default values in order of stability category are -- .1745, .1080, .0735, .0465, .0350 and .0235 If ISW(17) equals "1", the urban mode is assumed and default values in order of stability category are -- .1745, .1745, .1080, .0735, .0465 and .0465 The default values given do not depend on wind speed category.
SIGEPL	Standard Deviation of the Wind Elevation Angle for Building and Area Sources When ISW(16) Equals "1" -- This parameter array gives the standard deviation of the wind elevation angle for building and area sources by wind speed and stability or time-of-day category when ISW(16) equals "1". If ISW(16) equals "0", this parameter array is not read by the program and the values used for building and area sources are taken from SIGEPU. If ISW(16) equals "1", there are NSPEED values read (1 through NSPEED) per data card for stability categories 1 through NSTBLE. The units of SIGEPL are radians or degrees. If the value is greater than or equal to "1", the program assumes the units are degrees. There are no default values provided for SIGEPL.

e. Source Data. These data consist of all necessary information required for each source. These data are divided into three groups: (1)

parameters that are required for all source types, (2) parameters that are required for stack sources, and (3) parameters that are required for building sources and area sources. The order of input of these parameters is given at the end of this section. These data are not read by the program if NSOURC equals "0".

Parameter Name	
NUMSQ1	Source Identification Number -- This parameter is the source identification number and is a 1 to 5 digit integer. This number cannot be defaulted and cannot have a value larger than 14000. Sources must be input in ascending order of the source identification number, but source numbers need not necessarily be continuous.
DISP	Source Disposition -- This parameter is a flag that tells the program what to do with the source. If this parameter is not punched or has a value of "0", the program assumes this is a new source for which concentrations are to be calculated. Also, if the program is using an input tape, this new source will be merged into the old sources from tape or will replace a tape source with the same source identification number. If the parameter DISP has a value of "2", the program assumes that the tape input source having the same source identification number is to be deleted from the source inventory. The program removes the source as well as the concentration arrays for the source. If the parameter DISP has a value of "1", the program assumes the source strengths to be read from data card for this source are to be used to rescale the concentration values of the tape input source with the same source identification number. The new source strengths input from card replace the old values taken from the input tape and

Parameter Name	
DISP (Cont.)	the concentration arrays taken from tape are multiplied by the ratio of the new and old source strengths. This option can only be used with sources that were originally entered with the DISP = "0" option, not the DISP = "3" option. If the parameter DISP has a value of "3", the program assumes the source emission rate is to vary with wind speed category, stability or time-of-day category and season and reads the source emission rates into the array QSS1 below, rather than the array Q1. The affected source is treated by the program as if DISP was set to a value of "0".
TYPE1	Source Type -- This parameter is a flag that tells the program what type of source is being input. If this parameter is not punched or is "0", the program assumes a stack source. If this parameter has a value of "1", the program assumes a building source. Similarly, if this parameter has a value of "2", an area source is assumed.
DX1	Source X Coordinate -- This parameter gives the Cartesian X (east-west) or polar (range) coordinate, depending on ISW(15), of the source location in meters (X in Table 2-9) relative to the origin of the reference grid system being used. If DX1 is the range in polar coordinates and UTMX, UTMY above are greater than "0", DX1 is relative to (UTMX,UTMY).
DY1	Source Y Coordinate - This parameter gives the Cartesian Y (north-south) or polar (azimuth bearing) coordinate, depending on ISW(15), of the source location in meters or degrees (Y in Table 2-9) relative to the origin of the reference grid system being used. If DY1 is the azimuth

Parameter Name	
DY1 (Cont.)	in polar coordinates and UTMX, UTMY above are greater than "0", DY1 is relative to the point (UTMX,UTMY).
H1	Height of Emission -- This parameter gives the height above ground in meters of the pollutant emission. For building sources, this is the height of the building. For area sources, this is the characteristic height.
HS1	Source Elevation -- This parameter gives the terrain elevation in meters above mean sea level at the source location and is not used by the program unless receptor terrain elevations (ISW(8)) are being used.
Q1	Source Emission -- This parameter array gives the emission rate of the source for each season. If DISP above is "0" or "1", NSEASN values are read from the primary source data card. If DISP is "3", the source emission rates are read into QSS1 below from a secondary group of source data cards and this parameter is ignored. There are no default values provided for the parameter Q1 and the program assumes "0" is a valid source emission. The input units of source emission are mass per unit time and the default units are grams per second.
QSS1	Alternate Variable Source Emission -- This parameter array gives the emission rate of the source for each season, wind speed category and stability or time-of-day category and is used only if the parameter DISP above equals a value of "3". There are NSPEED values read per data card and NSTBLE data cards read per season, 1 through NSEASN. There are no dedefault values provided for the parameter QSS1 and the program assumes "0" is a valid source emission. The input units are the same as for Q1 above.

Parameter Name	
NVS1	Number of Particulate Size Categories -- This parameter gives the number of particulate size categories in the particulate distribution used in calculating ground-level concentration with gravitational settling and dry deposition occurring. The program assumes complete retention of the particulates at the ground surface with deposition occurring. If the parameter NVS1 is greater than zero, the program reads NVS1 values for each of the parameter variables VS1 and FRQ1 below. The maximum value of NVS1 is 20.
VS1	Settling Velocity -- This parameter array is read only if NVS1 above is greater than zero. This parameter is the settling velocity in meters per second for each particulate size category (1 through NVS1). No default values are provided for this parameter.
FRQ1	Mass Fraction of Particles -- This parameter array is read only if NVS1 above is greater than zero. This parameter is the mass fraction of particulates contained in each particulate size category (1 through NVS1). No default values are provided for this parameter.
Stack Source Parameters	
TS1	Stack Gas Exit Temperature -- This parameter gives the stack gas exit temperature (T_s in Table 2-9) in degrees Kelvin. If this parameter is negative or zero, its absolute value is added to the ambient air temperature to form the stack gas exit temperature. For example, if the stack gas exit temperature is 15 degrees Celsius above the ambient temperature, enter TS1 as "-15."

Stack Source Parameters

VOL1	Volumetric Emission Rate -- This parameter gives the volumetric emission rate in cubic meters per second. The volumetric emission rate is determined by the product of the inside stack area times the gas exit velocity. No plume rise is calculated if VOL1 is equal to "0".
RDS1	Stack Radius -- This parameter gives the inner stack radius in meters and no default is provided. This parameter is used to calculate the stack exit velocity for use in Equation (2-5), which adjusts the calculated plume rise to account for downwash effects when the wind speed at stack height approaches or exceeds the stack exit velocity. If the ratio of the exit velocity to the mean wind speed is greater than 1.5, no correction is made. If the ratio of the exit velocity to the mean wind speed is less than or equal to 1.0, plume rise is set equal to zero. The correction factor f given by Equation (2-5) ranges from 1.0 to 0 for exit velocity to mean wind speed ratios between 1.5 and 1.0. See Appendix G for a detailed discussion of the correction factor f. If RDS1 is input as "0" or not punched, the program assumes that there are no downwash effects and full plume rise is calculated.
S11	Length of Short Side -- This parameter gives the length in meters of the short side of a building or area source.
S21	Length of Long Side -- This parameter gives the length in meters of the long side of a building or area source.

4.1.3 Output Information

The LONGZ program generates four categories of program output. Each category is optional to the user. That is, the user controls all output generated by the program for a given run except warning and error messages. In the following paragraphs, each category of output is related to the specific input parameter that controls the output category. All program output are printed except for magnetic tape.

a. Input Parameter Output. The LONGZ program will print all of the input data except for source data if the parameter ISW(5) is set equal to a value of "1". An example of this output is shown in Figure 4-2 of Section 4.2.4 and in the example problem given in Appendix D.

b. Source Parameters Output. The LONGZ program will print the input card and tape source data if the parameters ISW(6) and ISW(7) are both set to a value of "1". Also, if ISW(2) -- the tape output option -- is set to a value of "2", a complete source output inventory listing is produced. An example of the printed source data is shown in Figure 4-3 of Section 4.2.4 and in the example problem given in Appendix D.

c. Seasonal/Annual Concentrations. The options ISW(3) and ISW(4) are used to specify whether seasonal output or annual output or both are to be generated. If seasonal (winter, spring, summer, fall) meteorological data are input, the program can be directed to produce tables of seasonal as well as annual concentrations by setting the parameters ISW(3) and ISW(4) equal to "1". Also, only seasonal tables are produced if ISW(3) equals "1" and ISW(4) equals "0". If the parameter NSEASN is set equal to a value of "1" and only annual output is selected, the program labels the output concentrations as annual concentrations. However, if seasonal output is selected with NSEASN equal to "1", the output tables are labeled as seasonal tables (season 1, season 2, etc.), requiring the user to keep track of the actual meteorological season. Example seasonal and annual output tables are shown in Figures 4-4 and 4-5 in Section 4.2.4 as well as Appendix D.

d. Magnetic Tape Output. The LONGZ program will write all input data and all concentration calculations to magnetic tape. These data are written to the logical unit numbers specified by the parameter array -- NOTFL. This tape must be assigned to the run prior to the execution of the LONGZ program and the tape(s) must be equated to the logical unit number(s) given in NOTFL. If seasonal meteorological input data are used, the program saves only seasonal concentrations on the output tape. If annual meteorological data are input, only the results of the annual calculations are saved. This output tape can be read back into the LONGZ program to print tables not output in the original run and/or to modify the source inventory for corrections or updates in the source emissions. The instructions on how to assign the output magnetic tape are given in Section 4.2.2 and approximations as to the length of magnetic tape required are given in Section 4.2.5.c. A more detailed description of the contents and format of the output tape file is given in Section 4.2.4.

4.2 USER'S INSTRUCTIONS FOR THE LONGZ PROGRAM

4.2.1 Program Description

The long-term (LONGZ) program is designed to calculate ground-level average concentrations produced by emissions from multiple stack, building and area sources. The ground-level concentrations can be calculated on a seasonal (monthly) or annual basis or both for a maximum of 14000 sources. The program is capable of producing the seasonal and/or annual results for each individual source input as well as the combined (summed) seasonal and/or annual results for multiple groups of user-selected sources. The program concentration calculations are performed for an input set of receptor coordinates defining a fixed receptor grid system and/or for discrete (arbitrarily placed) receptor points. The receptor grid system may be a right-handed Cartesian coordinate system or a polar coordinate system. In either case, zero degrees (north) is defined as the positive Y axis and ninety degrees (east) is defined as the positive X axis and all points are relative to a user-defined hypothetical origin (normally (X=0, Y=0), although the Universal Transverse Mercator (UTM) coordinates may be used as the Cartesian coordinate system).

Capabilities of the LONGZ program include:

- The capability to calculate long-term ground-level concentrations
- The capability to process up to 14000 sources
- The capability to model stacks, building sources and area sources in the same execution
- The capability to specify source locations anywhere within or outside of the receptor grid system or discrete receptor points
- The capability to produce either seasonal or annual results or both
- The capability to display concentrations from individual sources
- The capability to display combined (summed) concentrations from multiple user-defined subsets of the sources or from all sources

- The capability of saving the results of all calculations, the source data and the meteorological data on a master source/concentration inventory magnetic tape

- The capability of updating (adding to, modifying or deleting) a master source/concentration inventory magnetic tape

- The capability to specify a regular receptor array or a set of discrete (arbitrarily placed) points or both

- The capability to specify a right-handed Cartesian coordinate system or a polar coordinate system for the regular receptor array or for the discrete (arbitrarily placed) receptors

- The capability to specify terrain elevations for each receptor and source for concentration calculations

- The capability of using either seasonal or annual meteorological data

- The capability of specifying the number of wind speed, Pasquill stability or time-or-day and wind direction categories in the meteorological data

- The capability to vary source emissions by season or by wind speed category, Pasquill stability or time-of-day category and season (season is defined as winter, spring, summer and fall or annual only)

The LONGZ computer program is written in FORTRAN and is designed for use on a UNIVAC 1110 computer. The program requires approximately 50,000 words (UNIVAC 1110) of executable core for instruction and data storage. The program also requires from two to four input/output devices, depending on whether the tape input/output options are used. Input card image data is referenced as logical unit 5 and print output, which requires 132 character print columns, is referenced as logical unit 6. The optional tape input is referenced as logical unit 2 (default) and the output is referenced as logical unit 3 (default). The user has the option of either using the default logical unit numbers given here or specifying alternate logical unit numbers. Also, the LONGZ program requires random access mass storage referenced as logical unit 12. The mass storage is automatically assigned by the program and is transparent to the user. The computer program consists of a main program (LONGZ) and 7 subroutines (MODEL, BLOCKL, OUTPT, TITLR, INPOUP, ASSIGN and DEFFIL). The FORTRAN source code for each of these routines is given in Appendix B.

4.2.2 Control Language and Data Deck Setup

a. Control Language Requirements. The following illustrates the required ECL control statement runstream for a typical run on a UNIVAC 1110 Operating System:

```
1.        @RUN, priority  jobid,account,userid,
                                    time,pages


                                                       (Optional, used to
                                                       )direct print output
2.        @SYM PRINT$,,device                          <to a specific print
                                                       )device when running
                                                       (in batch mode


3.        @ASG,A  prog-file.
```

4.	@ASG,A data-file.	Optional, used only when the LONGZ program input data has been placed in a file or data element within a file.
5.	@ASG,options input-tape-file.,type, reel-number @USE nn,input-tape-file.	Optional, required only if ISW(1)=1
	@MOVE input-tape-file.,ℓ	Optional, required only if data on the input-tape-file is file ℓ+1 on tape, ℓ>1.
6.	@ASG,options output-tape-file.,type, reel-number @USE mm,output-tape-file.	Optional, required only if ISW(2)=1 or 2 and data are output to tape
	@MOVE output-tape-file.,ℓ	Optional, required only if the data-output-file is file ℓ+1, ℓ>1.
7.	@ASG,CP print-file. @BRKPT PRINT$/print-file	Optional, used to direct print output to a specific print device when running in demand mode
8.	@XQT prog-file.LONGZ	
9.	card-input-data	Input data cards for the LONGZ program when the program is run in batch mode

or

```
                                                  LONGZ input data
          @ADD data-file.                         cards have been
                                                  placed in a data
                                                  file

                or

                                                  LONGZ input data
                                                  cards have been
          @ADD  data-file.data-name               placed in a symbolic
                                                  element in a data
                                                  file

10.       @BRKPT    PRINT$                        Optional, used with
                                                  7 above to direct
          @FREE     print-file.                   the print output to
                                                  a specific print
          @SYM      print-file,,device            device

11.       @FIN
```

where

priority = job run priority

jobid = six-character user supplied job identification

account = account number

userid = 12-character user supplied project number or user number

time = execution time required in minutes

pages = output pages required

device = printer symbiont name, on site or remote, to which you desire the print file to go

prog-file = the name of the program file. This illustration assumes the user (installation) has assembled and collected (linked) the long-term program into this file and called the absolute program LONGZ

data-file = the name of an optional data file into which the user has placed the input card data for LONGZ

input-tape-file = a user supplied file name used to reference the optional source/concentration inventory input tape. This tape was created by a previous run of the LONGZ program

options = tape assignment options T, H, F, J, /W

- T -- temporary, tape
- H -- high density, use only if U9H is specified for type
- F -- tape file is to be labeled with a label that requires only the reel-number to be correct, use this option only on output permanent tapes that are to be labeled
- J -- specifies the tape is unlabeled. This option may not be allowed

at your installation for permanent tapes. However. the J option should be specified for scratch tapes

/W -- specifies the tape is an output tape and a write ring is to be inserted

The options follow the comma and are placed together in a continuous string.

type = the type of tape input/output device. Use 16N or U9V if the tape density is 1600 bpi or use U9H if the tape density is 800 bpi

reel-number = the physical tape reel-number assigned by the installation tape librarian. Each tape reel-number is unique. If a scratch tape is desired for output then type BLANK for reel-number

nn = the FORTRAN logical unit number with which the LONGZ program is to reference (read) the input tape. This number is defined under the NINFL parameter input option. This number cannot equal any of the standard I/O (card reader, printer, punch) device logical unit numbers and must be a value allowed by the UNIVAC NTRAN I/O routines at your installation. The default input unit number for LONGZ is "2"

ℓ = the number of file-marks to space over on the input tape to position the tape at the desired input data set. The MOVE card is only required if $\ell>1$.

output-tape-file = a user supplied file name used to reference the optional source/concentration inventory output tape. This tape must be assigned using the W option.

mm = the FORTRAN logical unit number with which the LONGZ program is to reference (write) the output tape. This number is defined under the NOTFL parameter input option. This number cannot equal any of the standard I/O (card reader, printer, punch) device logical unit numbers and must be a value allowed by the UNIVAC NTRAN I/O routines at your installation. The default output unit number for LONGZ is "3".

print-file = optional, user supplied, file name to be used for the LONGZ print output file. If the user is running from an interactive terminal and this option is not used all print output will be printed at the terminal in 132 character line images. As the print output volume could be large, it is recommended that the print-file option be used and the print file be SYM'ed to an on-site printer (in 10) after the execution of LONGZ.

card-input-data = LONGZ program input card data defined in Section 4.1.2 and shown in Figure 4-1. If the user is running from an interactive terminal, it is recommended that the data be placed in a data file or in a symbolic element within a data file prior to execution of LONGZ. The user would then use an @ADD command to add the data to the run stream.

b. Data Deck Setup. The card input data required by the LONGZ program depends on the program options desired by the user. The card input deck may be partitioned into five major groups of card data. Figure 4-1 illustrates the input deck setup. Note that some of the card groups shown may be omitted from the input deck, depending on the input options chosen. The five major input deck groups are:

1. Title Card (One data card, always included in the input deck).

2. Program Option and Control Cards (The first two cards of this group are always included in the input deck. However, some of the parameters on these two cards may not be used when tape input is used. The remaining cards in this group are included only if NGROUP is greater than "0").

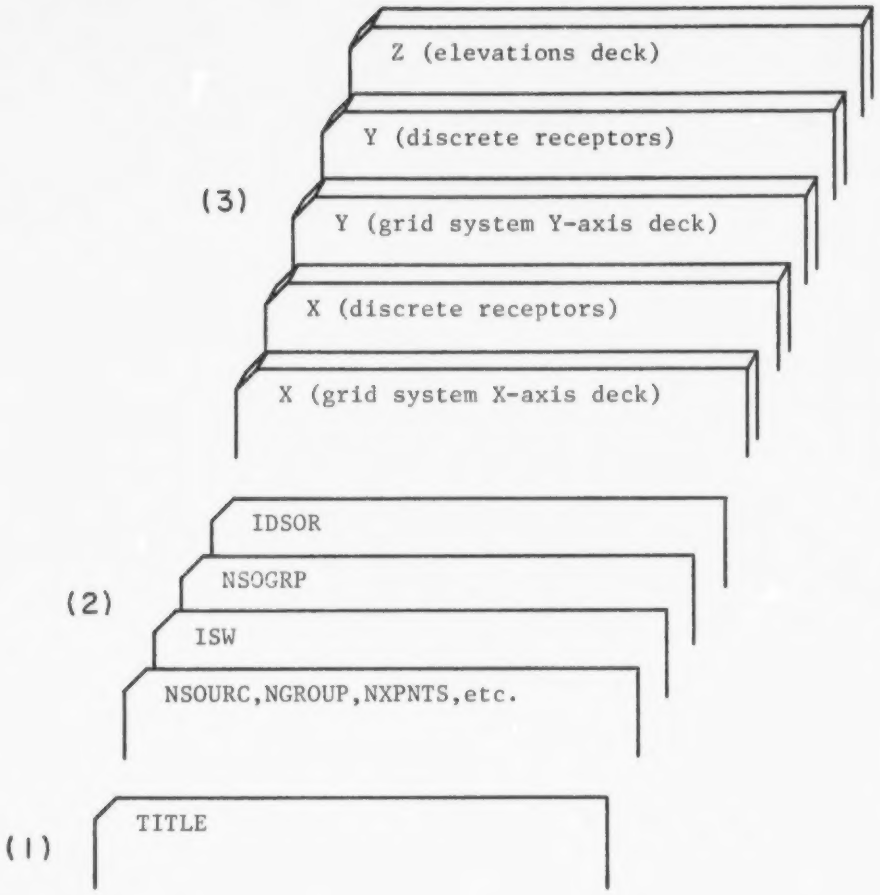

Z (elevations deck)
Y (discrete receptors)
(3)
Y (grid system Y-axis deck)
X (discrete receptors)
X (grid system X-axis deck)
IDSOR
NSOGRP
(2)
ISW
NSOURC,NGROUP,NXPNTS,etc.
TITLE
(1)

FIGURE 4-1. Input data deck setup for the LONGZ program.

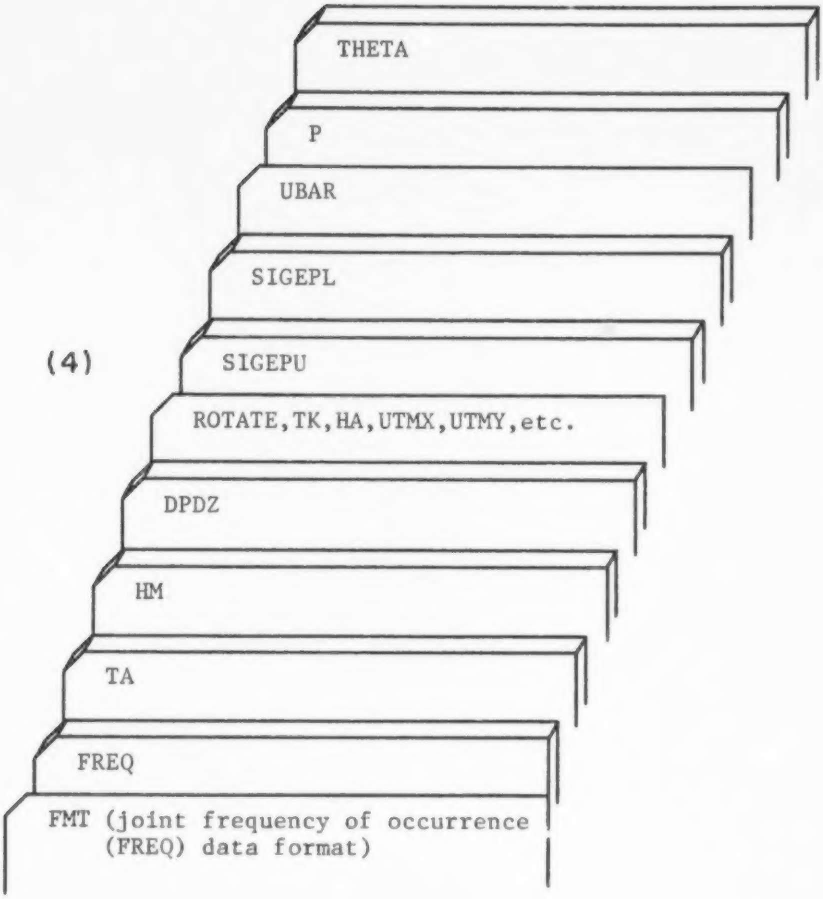

THETA
P
UBAR
SIGEPL
(4)
SIGEPU
ROTATE,TK,HA,UTMX,UTMY,etc.
DPDZ
HM
TA
FREQ
FMT (joint frequency of occurrence (FREQ) data format)

FIGURE 4-1. (Continued)

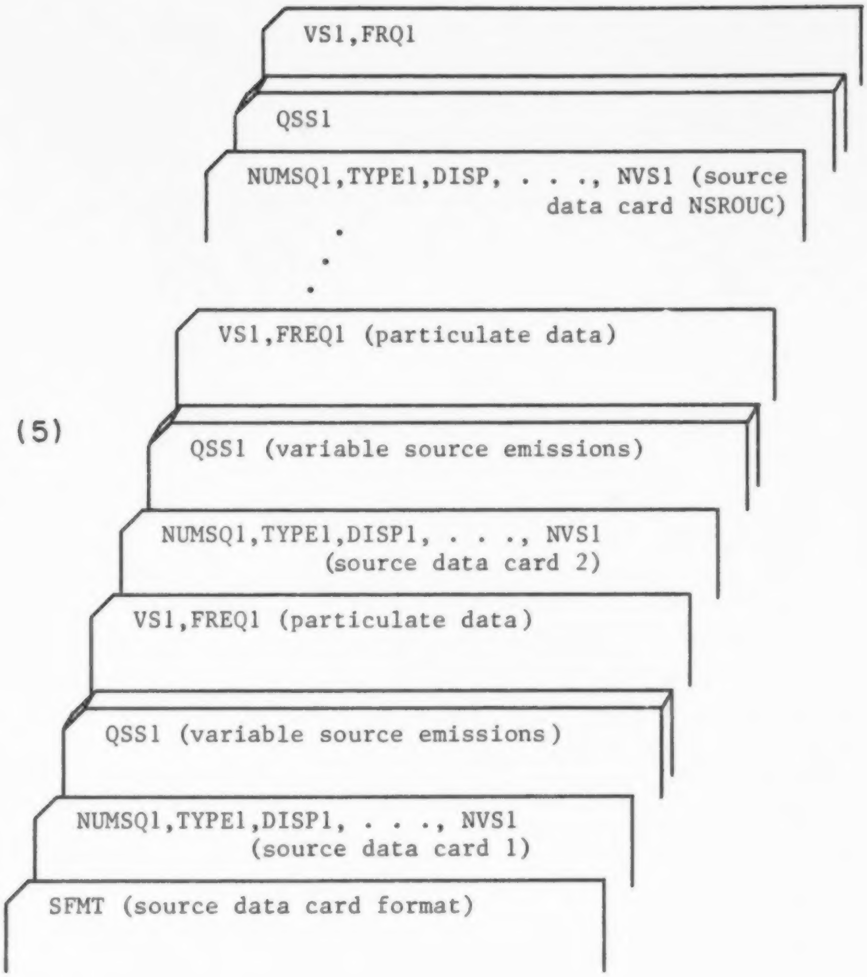

VS1,FRQ1
QSS1
NUMSQ1,TYPE1,DISP, . . ., NVS1 (source data card NSROUC)
VS1,FREQ1 (particulate data)
(5)
QSS1 (variable source emissions)
NUMSQ1,TYPE1,DISP1, . . ., NVS1 (source data card 2)
VS1,FREQ1 (particulate data)
QSS1 (variable source emissions)
NUMSQ1,TYPE1,DISP1, . . ., NVS1 (source data card 1)
SFMT (source data card format)

FIGURE 4-1. (Continued)

3. Receptor Data Cards (The number of data cards included in this group depends on the parameters NXPNTS, NYPNTS, NXWYPT and ISW(8). These cards are not included in the input deck if tape input is used, ISW(1) equals "1" or "2").

4. Meteorological Data Cards (This card group is included in the input deck only if tape input is not used or if the tape input switch (ISW(1)) is set equal to "2". Also, the first card (FMT) in this group is included in the input deck only if ISW(11) equals "1").

5. Source Data Cards (This card group is included in the input deck only if NSOURC is greater than "0". Also, the first card (SFMT) is included only if ISW(12) equals "1". The variable source emission cards (QSS1) are included in the deck only if the parameter DISP on the previous source card equals "3". Also, the particulate data cards are included in the data deck only if NVS1 on the previous source card is greater than "0").

4.2.3 Input Data Description

Section 4.1.2 provides a summary description of all input data parameter requirements for the LONGZ program. This section provides the user with the FORTRAN format and order in which the program requires the input data parameters. The input parameter names used in this section are the same as those introduced in Section 4.1.2. Two forms of input data may be input to the program. One form is card image input data (80 characters per record) in which all required input data may be entered. The other form is magnetic tape on which some of the required data were stored as part of a previous run of the LONGZ program. Both forms of input are discussed below.

a. Card Input Requirements. The LONGZ program reads all card image input data in a fixed-field format with the use of a FORTRAN "A", "I" or "F" editing code (format). Each parameter value must be punched in a fixed-field on the data card defined by the start and end card columns specified for the variable. Table 4-4 identifies each variable by name and respective card group. Also, Table 4-4 specifies the card columns (fixed-field) for the parameter value and the editing code ("A", "I" or "F") used to interpret the parameter value. Parameters using an "A" editing code are alpha-numeric data items used primarily for labeling purposes. These data items can be punched anywhere in the specified data columns and can consist of any character information. If not punched, these data items are interpreted as blanks. Parameters using an "I" editing code are integer (whole number) data items. These data items must be numeric punches only and must be punched (right justified) so the units digit of the number is in the far right column of the field. If the punch field for the variable is not punched (left blank), it is interpreted as zero. Parameters using an "F" editing code are real number data items. These data items can be punched like integer ("I") data items (right justified) if they are whole numbers. However, they must be punched with a decimal point (".") if they contain a fractional part. These data items are interpreted as zero if not punched.

Card Group 1 in Table 4-4 gives the print output page heading and is always included in the input data deck. Any information to identify the output listing or data case may be punched into this card. If the card is left blank, the heading will consist of only the output page number.

Card Group 2 contains the parameters that specify the number of input card sources, size of receptor arrays, the number of categories in the input meteorological data, and the input source units and output concentration units. These parameters are regarded as options because, if any are zero, a particular function is not performed. *Many of the*

TABLE 4-4

LONGZ PROGRAM CARD INPUT PARAMETERS,
FORMAT AND DESCRIPTION

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
1	TITLE	1-80	20A4	80 character page heading label
2	NSOURC	1-5	I5	Number of card image input sources to be read under Card Groups 18a through 18c below
	NGROUP	6-9	I4	Number of different source combinations used to print concentration (maximum = 1000). A source combination consists of one or more sources
	NXPNTS*	10-13	I4	Number of receptors in the X-axis of the receptor grid system
	NYPNTS*	14-17	I4	Number of receptors in the Y-axis of the receptor grid system
	NXWYPT*	18-21	I4	Number of discrete (arbitrarily placed) receptor points
	NSEASN*	22-23	I2	Number of seasons in the input meteorological data. The maximum for this parameter is 4 and if blank or 0, the default is 1

*These parameters are set automatically by the program and cannot be changed if tape input (ISW(1) = 1 or 2) is being used.

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
2 (Cont.)	NSTBLE*	24-25	I2	Number of Pasquill stability or time-of-day categories in the joint frequency of occurrence of wind speed and direction. The maximum is 6 and the default is 5 if blank or 0
	NSORX	26-30	I5	Total number of non-deleted sources in the output tape inventory at the completion of the run. If not punched or zero, the program uses NSOURC or NSOURC plus the number of input tape sources. Necessary only if both input and output tapes are used with NSOURC greater than zero.
	NSPEED*	31-32	I2	Number of wind speed categories in the joint frequency of occurrence of wind speed and direction. The maximum is 6 and 6 is the default value if blank or 0
	NSCTOR*	33-34	I2	Number of wind direction sector categories in the joint frequency of occurrence of wind speed and direction. The maximum is 16 and the default is 16 if blank or 0

*These parameters are set automatically by the program and cannot be changed if tape input (ISW(1) = 1 or 2) is being used.

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
2 (Cont.)	NSTOP	35-39	I5	Source number of last source on input tape to be read by the program. If not punched or zero, the program reads to the end-of-file
	LUNT*	40-63	6A4	24 characters giving the concentration print output units. This label is automatically filled if the parameter TK on Card Group 12 is defaulted. If this label is punched, start in column 40 and include leading and ending parentheses
	LKNT*	64-75	3A4	12 characters giving the source emission rate input units. This label is automatically filled if the parameter TK on Card Group 12 is defaulted. If this label is punched, start in column 64 and include leading and ending parentheses
3	ISW(1)	1-2	I2	Blank or 0 = input tape not used 1 = tape input read from the logical units specified by NINFL

*These parameters are set automatically by the program and cannot be changed if tape input (ISW(1) = 1 or 2) is being used.

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
3 (Cont.)	ISW(2)	3-4	I2	Blank or 0 = output tape not used 1 = tape output is written to the logical units specified by NOTFL 2 = tape output is written to the logical units specified by NOTFL and the program produces a listing of the source output inventory
	ISW(3)	5-6	I2	Blank or 0 = seasonal concentration is not printed 1 = print seasonal concentration
	ISW(4)	7-8	I2	Blank or 0 = annual concentration is not printed 1 = print annual concentration
	ISW(5)	9-10	I2	Blank or 0 = program model and control parameters are not printed 1 = print input model and control parameters
	ISW(6)	11-12	I2	Blank or 0 = do not print input card sources 1 = print input card sources

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
3 (Cont.)	ISW(7)	13-14	I2	Blank or 0 = do not print input tape sources 1 = print input tape sources
	ISW(8)	15-16	I2	Blank or 0 = do not read terrain elevations from Card Group 7b 1 = read terrain elevation data from Card Group 7b
	ISW(9)	17-18	I2	Blank or 0 = wind speed power law is based on emission height above airport or weather station. If the emission height is below the airport or weather station no power law is used 1 = wind speed power law is based on height above terrain and a power law is always used
	ISW(10)	19-20	I2	Blank or 0 = all print output is written to logical unit 6 n > 0 = all print output is written to the logical unit n. If n is not equal to 56, two end-of-file marks are written and the unit is rewound

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
3 (Cont.)	ISW(11)	21-22	I2	Blank or 0 = Card Group 8a is not read by the program 1 = Card Group 8a (FMT) is to be read by the program
	ISW(12)	23-24	I2	Blank or 0 = Card Group 18 is not read by the program 1 = Card Group 18 (SFMT) is to be read by the program
	ISW(13)	25-26	I2	Blank or 0 = receptor grid system is in rectangular (Cartesian) coordinates 1 = receptor grid system is in polar coordinates relative to the point specified by UTMX and UTMY
	ISW(14)	27-28	I2	Blank or 0 = discrete (arbitrarily placed) receptors are in rectangular (Cartesian) coordinates 1 = discrete receptors are in polar coordinates relative to the point specified by UTMX and UTMY

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
3 (Cont.)	ISW(15)	29-30	I2	Blank or 0 = source locations are in rectangular (Cartesian) coordinates 1 = source locations are in polar coordinates relative to the point specified by UTMX and UTMY
	ISW(16)	31-32	I2	Blank or 0 = the same turbulent intensities (SIGEPU) are used for all source types 1 = different turbulent intensities are to be entered for stacks and for building and area sources. Use SIGEPU for stacks (TYPE1=0) and SIGEPL for building (TYPE1=1) and area (TYPE1=2) sources. No default turbulent intensities are provided for this option
	ISW(17)	33-34	I2	Blank or 0 = default turbulent intensities are Cramer, et al. (1975) rural values if ISW(16)=0. The program will not use default turbulent intensities if ISW(16)=1 1 = default turbulent intensities are Cramer, et al.(1975) urban values if ISW(16)=0. The program will not use default turbulent intensities if ISW(16)=1

TABLE 4-4 (Continued

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
3 (Cont.)	ISW(18)	35-36	I2	Reserved for future option
	ISW(19)	37-38	I2	Reserved for future option
	ISW(20)	39-40	I2	Reserved for future option
	NINTP	41-42	I2	Blank or 0 = program assumes a maximum of one input tape $3 \geq n > 0$ = number of input tapes
	NOTTP	43-44	I2	Blank or 0 = program assumes a maximum of one output tape $3 \geq n > 0$ = number of output tapes
	NINFL(1)	45-46	I2	Blank or 0 = program assumes the first input tape is logical unit 2 $n > 0$ = logical unit number used to reference the first input tape
	NINFL(2)	47-48	I2	Blank or 0 = program assumes there is only one input tape $n > 0$ = logical unit number used to reference the second input tape

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
3 (cont.)	NINFL(3)	49-50	I2	Blank or 0 = program assumes there are no more than two input tapes n > 0 = logical unit number used to reference the third input tape
	NOTFL(1)	51-52	I2	Blank or 0 = program assumes the first output tape is logical unit 3 n > 0 = logical unit number used to reference the first output tape
	NOTFL(2)	53-54	I2	Blank or 0 = program assumes there is no more than one output tape n > 0 = logical unit number used to reference the second output tape
	NOTFL(3)	55-56	I2	Blank or 0 = program assumes there are no more than two output tapes n > 0 = logical unit numbers used to reference the third output tape

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
4	NSOGRP	1-4 5-8 ⋮ 77-80	20I4	Array used to specify the number of source ID-numbers you are using to define each source combination. There are NGROUP values read here. This data card is omitted from the input card deck if NGROUP = 0. There are a maximum of 1000 values that can be input here
5	IDSOR	1-6 7-12 ⋮ 73-78 (for each card)	13I6	Array used to specify the source ID-numbers to use in forming the combined source output and individual source output. There are a maximum of 1000 values that can be input here. This data card group is omitted from the input card deck if NGROUP = 0
6**	X	1-10 11-20 ⋮ 71-80 (for each card)	8F10.0	Array of NXPNTS receptor points in meters in ascending order defining the X-axis of the receptor grid system. If only the first two points are non-zero, the program assumes the first is the start of the axis and the second is the increment it uses to generate the remaining points. This card group is omitted from the input data deck if NXPNTS = 0

**These card groups are omitted from the input card deck if tape input (ISW(1) = 1 or 2) is being used. The information for these parameters is taken from the input tape.

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
6a**	X	1-10 11-20 ⋮ 71-80 (for each card)	8F10.0	Array of NXWYPT discrete receptor points in meters. This card group is omitted from the input data deck if NXWYPT = 0
7**	Y	1-10 11-20 . . . 71-80 (for each card)	8F10.0	Array of NYPNTS receptor points in meters or degrees depending on ISW(13) in ascending order defining the Y-axis of the receptor grid system. If only the first two points are non-zero, the program assumes the first is the start of the axis and the second is the increment used to generate the remaining points. This card group is omitted from the input data deck if NYPNTS = 0
7a**	Y	1-10 11-20 ⋮ 71-80 (for each card)	8F10.0	Array of NXWYPT discrete receptor points in meters or degrees depending on ISW(14). This card group is omitted from the input data deck if NXWYPT = 0

**These card groups are omitted from the input card deck if tape input (ISW(1) = 1 or 2) is being used. The information for these parameters is taken from the input tape.

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
7b**	Z	1-10 11-20 ⋮ 71-80 (for each card)	8F10.0	Array of terrain elevations in meters for each receptor of the NXPNTS by NYPNTS grid system. This card group is omitted from the input data deck if either ISW(8) = 0 or NXPNTS=0 or an input tape is being used. See the text for the order of values input to this card group
7c**	Z	1-10 11-20 ⋮ 71-80 (for each card)	8F10.0	Array of terrain elevations in meters for each discrete receptor. This card group is omitted from the input card deck if ISW(8) = 0 or NXWYPT = 0
8	FMT	1-80	20A4	Array specifying the format used to read Card Group 8a (not read if ISW(11) = 0, default format is 6F10.0)

These card groups are omitted from the input card deck if **tape input (ISW(1) = 1 or 2) is being used. The information for these parameters is taken from the input tape.

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
8a***	FREQ	1-10**** 11-20 ⋮ 51-60 (for each card)	FMT	Array giving the joint frequency of occurrence of the wind speed and direction for each stability or time-of-day category and each season expressed as a percentage or as a fraction. See the text for the order of input values
9***	TA	1-10 11-20 ⋮ 51-60 (for each card)	6F10.0	Array of ambient air temperatures in degrees Kelvin as a function of stability or time-of-day category and season. See the text for the order of input values
10***	HM	1-10 11-20 ⋮ 51-60 (for each card)	6F10.0	Array of mixing layer depths in meters as a function of wind speed and stability or time-of-day category and season. See the text for the order of input values

***These card groups are omitted from the input card deck if tape input with ISW(1) = 1 is being used and the information for these parameters is taken from the input tape. However, if ISW(1) = 0 or 2, these card groups are read by the program.

****These are the default card columns used for this array and are not applicable if FMT on Card Group 8 is input.

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
11***	DPDZ	1-10 11-20 ⋮ 51-60 (for each card)	6F10.0	Array of the vertical gradient of potential temperature in degrees Kelvin per meter as a function of wind speed and stability or time-of-day category. See the text for the order of input values.
12***	ROTATE	1-7	F7.0	Wind direction correction parameter used to correct for any difference in north as defined by the reference receptor grid system and north as defined by the weather station at which the wind data were recorded. The value of ROTATE is subtracted from each wind direction category
	TK	8-17	F10.0	Model units conversion factor used to produce the desired output concentration units from the input source emission rate units. The concentration default for TK is 1 x 10^6 micrograms per gram assuming output in micrograms per cubic meter and input source units in grams per second

***These card groups are omitted from the input card deck if tape input with ISW(1) = 1 is being used and the information for these parameters is taken from the input tape. However, If ISW(1) = 0 or 2, these card groups are read by the program.

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
12*** (Cont.)	TK (Cont.)			If the default is chosen, the parameters LUNT and LKNT above on Card Group 2 are automatically set
	HA	18-24	F7.0	Elevation in meters (MSL) of airport or weather station at which the meteorological data were recorded. The default value is zero
	UTMX	25-31	F7.0	East-west Cartesian (UTM) coordinate in meters of the origin for polar coordinates. The default value is zero
	UTMY	32-38	F7.0	North-south Cartesian (UTM) coordinate in meters of the origin for polar coordinates. The default value is zero
	G	39-45	F7.0	Acceleration due to gravity in meters per second squared. The default is 9.8 m/sec^2
	ZR	40-52	F7.0	Height in meters above ground at airport or weather station at which the wind speed was measured. The default value is 6.096 meters

***These card groups are omitted from the input card deck if tape input with ISW(1) = 1 is being used and the information for these parameters is taken from the input tape. However, if ISW(1) = 0 or 2, these card groups are read by the program.

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
12*** (Cont.)	GAMMA1	53-59	F5.0	Air entrainment coefficient for an adiabatic or unstable atmosphere. The default is 0.6
	GAMMA2	60-66	F5.0	Air entrainment coefficient for a stable atmosphere. The default is 0.66
	DECAY	67-73	F11.0	Coefficient (seconds^{-1}) of time dependent pollutant removal by physical or chemical processes. Default is zero or no decay
13***	SIGEPU	1-10 11-20 ⋮ 51-60 (for each card)	6F10.0	Standard deviation of the wind elevation angle in radians or degrees for stack sources (and building and area sources, if ISW(16)=0). See the text for the order and default values for this array. Default values are provided only if ISW(16)=0 and only if blank cards are input or cards with SIGEPU=0 are input.
14***	SIGEPL	1-10 11-20 ⋮ 51-60 (for each card)	6F10.0	Standard deviation of the wind elevation angle in radians or degrees for building and area sources when ISW(16)=1. See the text for the order of values for this array. This card group is not read by the program if ISW(16) equals 0. No default values are provided for SIGEPL.

***These card groups are omitted from the input card deck if tape input with ISW(1) = 1 is being used and the information for these parameters is taken from the input tape. However, if ISW(1) = 0 or 2, these card groups are read by the program.

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
15***	UBAR	1-10 11-20 ⋮ 51-60 (for each card)	6F10.0	Array containing the median value of each wind speed category in meters per second. The default values are 0.75, 2.5, 4.3, 6.8, 9.5 and 12.5 m/sec for the standard STAR summary wind-speed categories. Default values are provided if a blank card is input or any value of UBAR is zero.
16***	P	1-10 11-20 ⋮ 51-60 (for each card)	6F10.0	Array of wind-speed power law exponents as a function of wind speed and stability or time-of-day categories. See the text for the order of values and default values Default values are provided if blank cards are input or any value of P is zero.
17***	THETA	1-10 11-20 ⋮ 71-80 (for each card)	8F10.0	Array of wind direction sector angles in degrees beginning with the first direction category used in the joint frequency of occurrence of wind speed and direction (normally zero degrees north). NSCTOR values are read and, if the first two values are zero, this array is defaulted to the standard direction angles 0.0, 22.5, 45.0, . . ., 337.5 degrees. Default values are provided if two blank cards are input.

***These card groups are omitted from the input card deck if tape input with ISW(1) = 1 is being used and the information for these parameters is taken from the input tape. However, if ISW(1) = 0 or 2 these card groups are read by the program.

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
18	SFMT	1-80	20A4	Array specifying the format used to read Card Group 18a (not read if ISW(12) = 0). Default format is (I5, 2I1, 6F7.0, 4F6.0, F5.0, I2)
18a	NUMSQ1	1-5	I5	Source identification number. Input all sources in ascending order of the identification number. Card Groups 18a through 18c are omitted from the input data deck if NSOURC equals zero. Remember to group Card Groups 18a through 18c together as a set for each input source
	TYPE1	6	I1	Source type Blank or 0 = stack 1 = building 2 = area
	DISP	7	I1	Source disposition Blank or 0 = new input source or replace old tape source if it has same ID-number. Next card group read is 18a if NVS1>0. Otherwise, it is Card Group 18a 1 = use source emission rates on this card to rescale or recalculate concentrations for source NUMSQ1. Next card group read is 18a

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
18a (Cont.)	DISP (Cont.)			2 = delete incoming tape source and concentration for source NUMSQ1. Next card group read is 18a 3 = do not use Q1 on this data card, but read variable emission rates next into QSS1 from Card Group 18b. Treated as if DISP equaled zero
	Q1(1)	8-14	F7.0	Source emission rate in units of mass per unit time for season 1 (winter) or annual. The default value is zero
	Q1(2)	15-21	F7.0	Source emission rate in units of mass per unit time for season 2 (spring). The default is zero
	Q1(3)	22-28	F7.0	Source emission rate in units of mass per unit time for season 3 (summer). The default value is zero
	Q1(4)	29-35	F7.0	Source emission rate in units of mass per unit time for season 4 (fall). The default value is zero
	DX1	36-42	F7.0	Cartesian X coordinate of the source in meters or the range in polar coordinates in meters, depending on ISW(15)

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
18a (Cont.)	DY1	41-49	F7.0	Cartesian Y coordinate of the source in meters or the azimuth bearing in polar coordinates in degrees depending on ISW (15)
	H1	50-55	F6.0	Height above the ground of the emission in meters
	HS1	56-61	F6.0	Elevation in meters above mean sea level at the source location
	TS1 or S11	62-67	F6.0	This field depends on the source type -- if TYPE1 = 0, TS1 = stack gas exit temperature in degrees Kelvin TYPE1 = 1 or 2, S11 = length of the short side of the building or area source in meters
	VOL1 or S21	68-73	F6.0	This field depends on the source type -- if TYPE1 = 0, VOL1 = stack gas volumetric emission rate (m^3/sec) TYPE1 = 1 or 2, S21 = length of the long side of the building or area source in meters
	RDS1	74-78	F5.0	Interior stack radius in meters used to limit plume rise to account for downwash effects. See Section 2.2 for the proper value to input here

TABLE 4-4 (Continued)

Card Group	Parameter Name	Card Columns	FORTRAN Edit Code (Format)	Description
18a (Cont.)	NVS1	79-80	I2	Number of particulate size categories in the particulate distribution for concentration with depletion due to dry deposition. The maximum value of this parameter is 20. If terrain elevations are being used, this parameter must not be punched or must equal zero
18b	QSS1	1-10 11-20 ⋮ 51-60 (for each card)	6F10.0	Variable source emission rates, read only if DISP on Card Group 18a equals 3. See the text for the order of input of these values
18c	VS1	1-10 11-20 ⋮ 71-80 (for each card)	8F10.0	Array of settling velocities in meters per second for each particulate size category. This card group is omitted from the input data deck if NVS1=0
	FRQ1	These values immediately follow the values of VS1 on the same data card	8F10.0	Array of mass fraction of the particulate distribution for each category. The sum of the fractions in this array should total 1 (100% of the distribution). This card group is omitted from the input data deck if NVS1=0.

parameters on this card may alter the form of the input deck because they specify how many data items to input to the program. The parameter NSOURC specifies how many data card sources to input or how many times the program is to read Card Group 18a. If NSOURC is zero, Card Groups 18 through 18c are omitted from the input data deck. The parameter NGROUP is used to group selected sources into a combined output by summing the concentration arrays of the selected sources. The user may specify up to a maximum of 1000 different source combinations. If NGROUP is left blank or punched zero, Card Groups 4 and 5 are omitted from the input card deck and the program will not print any concentration tables. NGROUP must be input greater than zero in order to produce concentration tables and the value input specifies how many values are to be read from Card Group 4 (NSOGRP). The parameters NXPNTS, NYPNTS and NXWYPT define the size of the program receptor point arrays. The maximum values of these parameters are limited by the core-use Equation (4-1) given under NXPNTS in Section 4.1.2. However, the limit (E) given in Equation (4-1) may be increased by increasing the PARAMETER MMM shown on line number 22 in the FORTRAN listing of the main LONGZ program. If an input tape is being used, these parameters are normally ignored by the program because these values are taken from the input tape. The remaining parameters on Card Group 2 specify the number of seasons (NSEASN), the number of Pasquill stability or time-of-day categories, the total number of sources output to tape (NSORX), the number of wind speed categories (NSPEED), the number of wind direction categories (NSCTOR), the last source desired from an input tape (NSTOP) and the units of concentration and input source emission units, LUNT and LKNT, respectively.

Card Group 3 gives the values of the program option array ISW. This card is always included in the input data deck. However, the values of ISW(9) and ISW(13) through ISW(15) are automatically set by the program if you are using an input (source/concentration inventory) tape. The options on this card that determine whether or not some card groups are included in the input data deck are ISW(1) and ISW(8). If ISW(8) is left blank or punched zero, Card Group 7b is omitted from the input data deck. If ISW(1) is equal to "1" (indicating an input data tape and using the old meteorological data from the tape), Card Groups 8 through 17 are omitted from the input data deck. Also, if ISW(11) is left blank or punched zero, Card Group 8 is omitted from the input deck and if ISW(12) is blank or zero, Card Group 18 is omitted from the input deck.

Card Groups 4 and 5 always occur together and are included in the input card deck only if NGROUP is greater than zero. Card Group 4 is the array NSOGRP used to specify the number of ID-numbers used to define each source combination. Each value in NSOGRP specifies the number of source ID-numbers to be read from Card Group 5 (IDSOR) in consecutive order for each source combination. A positive source ID-number punched into the array IDSOR indicates to include that source in the combination. A negative source ID-number indicates to include that source as well as all source ID-numbers less in absolute value, up to and including the previous positive source ID-number punched if it is part of the same group of ID-numbers defining a combination. If the negative value is the first ID-number of a group of ID-numbers, it as well as sources less in absolute values of ID-number are included in the source combination. See examples given under NSOGRP and IDSOR in Section 4.1.2 and the example problem in Appendix D. The data values are read from Card Group 4 using 4 card columns per value with a maximum of 1000 values and from Card Group 5 using 6 card columns per value, 13 values per card with a maximum of 1000 values.

Card Groups 6 through 7b specify the X, Y and Z coordinates of all receptor points. Card Groups 6, 7 and 7b are omitted from the input card deck if the parameters NXPNTS and NYPNTS equal zero or if an input tape is being used. Also, Card Groups 7b and 7c are omitted if ISW(8) equals "0" or no terrain elevations are being used. Card Groups 6a, 7a and 7c are also omitted from the input card deck if the parameter NXWYPT is zero or if an input tape is being used. Each of these card groups uses a 10 column field for each receptor value and 8 values per data card. The number of data cards required for each card group is defined by the values of the parameters NXPNTS, NYPNTS and NXWYPT. Values input on Card Groups 6 and 7 are always in ascending order (west to east, south to north, 0 to 360 degrees). The terrain elevations for the grid system on Card Group 7b begin in the southwest corner of the grid system or at 0 degrees for polar coordinates. The first data card(s) contain the elevations for each receptor on the X axis (1 to NXPNTS) for the first Y receptor coordinate. A new data card is started for the elevations for each successive Y receptor coordinate. A total of NYPNTS groups of data cards containing NXPNTS values each is required for Card Group 7b. The elevations for the discrete receptors in Card Group 7c are punched across the card for as many cards as required to satisfy NXWYPT elevation values.

Card Groups 8 through 17 specify the meteorological data and model constants and are included in the input data deck only if an input tape is not being used or an input tape is used with ISW(1) equal to "2". Card Group 8 is input only if ISW(11) equals "1" and specifies the format FMT which the program uses to read the card data in Card Group 8a. If Card Group 8 is omitted from the input deck (ISW(11) equals "0"), the program assumes the format is (6F10.0) or there are 6 values per card occupying 10 columns each including the decimal point (period). Card Group 8a is the set of data cards giving the joint frequency of occurrence of wind speed and wind direction (FREQ) by season and Pasquill stability category or time-of-day category. The joint frequency of occurrence data are input to the program in a deck that contains NSEASN seasons, NSTBLE stability or time-of-day categories within each season, NSCTOR wind direction categories within each stability category and NSPEED wind speed categories within each direction category. The values for each wind speed category (1 to NSPEED) are punched across each data card and are read using the format given in Card Group 8 or the default format used when Card Group 8 is omitted. The first card of each stability category is for direction category 1 (normally north), the second card for direction category 2 (normally north-northeast), down to the last direction category (normally north-northwest). Starting with season 1 (normally winter), the card group contains a set of these (NSCTOR) cards for each stability or time-of-day category, 1 through NSTBLE. The program requires NSCTOR*NSTBLE*NSEASN data cards in this card group. This data deck is normally produced by the STAR program of the National Climatic Center (NCC). Card Group 9 is the average ambient air temperature (TA). NSTBLE values are read from each data card in this group and there is one data card for each season, 1 through NSEASN. Card Group 10 is the median mixing layer depth (HM) for each speed and stability or time-of-day category and season. The program requires NSPEED values per data card and one data card for each stability or time-of-day category, 1 to NSTBLE. A group of these NSTBLE cards is required for each season (1 to NSEASN) for a total of NSTBLE*NSEASN data cards in Card Group 10. Card Group 11 is the vertical gradient of potential temperature (DPDZ) for each wind speed and stability or time-of-day category. NSPEED values are punched across the card and NSTBLE cards (1 to NSTBLE) are punched for this group. Card Group 12 contains meteorological and model constants; a detailed description of these parameters (ROTATE, TK, HA, UTMX, UTMY, G, GAMMA1, GAMMA2 and DECAY) is given in Section 4.1.2 above. Card Group 13 gives the standard deviation of the wind elevation angle (SIGEPU) for stack sources only, if ISW(16) equals "1", or for both stack sources and building and area sources, if ISW(16) equals "0". These values are given by stability or time-of-day category and wind speed category. The program reads NSPEED values from NSTBLE (1 through NSTBLE) data cards in this group. Default values for this parameter are provided only if ISW(16) equals "0" and only if the respective value is zero or not punched. The default values depend only on the stability category and ISW(17), rural or urban mode option. The default values for SIGEPU are shown in Table 4-5. Card Group 14 gives the standard deviation of the wind elevation angle (SIGEPL) for

TABLE 4-5

DEFAULT VALUES FOR THE LONGZ METEOROLOGICAL PARAMETERS

	Pasquill Stability Category	Wind Speed Category (UBAR)					
		1 (.75 mps)	2 (2.5 mps)	3 (4.3 mps)	4 (6.8 mps)	5 (9.5 mps)	6 (12.5 mps)
		- SIGEPU -					
RURAL MODE (ISW(16)="0" and ISW(17)="0")	A	.1745	.1745	.1745	.1745	.1745	.1745
	B	.1080	.1080	.1080	.1080	.1080	.1080
	C	.0735	.0735	.0735	.0735	.0735	.0735
	D	.0465	.0465	.0465	.0465	.0465	.0465
	E	.0350	.0350	.0350	.0350	.0350	.0350
	F	.0235	.0235	.0235	.0235	.0235	.0235
URBAN MODE (ISW(16)="0" and ISW(17)="1")	A	.1745	.1745	.1745	.1745	.1745	.1745
	B	.1745	.1745	.1745	.1745	.1745	.1745
	C	.1080	.1080	.1080	.1080	.1080	.1080
	D	.0735	.0735	.0735	.0735	.0735	.0735
	E	.0465	.0465	.0465	.0465	.0465	.0465
	F	.0465	.0465	.0465	.0465	.0465	.0465
		- P -					
	A	.10	.10	.10	.10	.10	.10
	B	.15	.10	.10	.10	.10	.10
	C	.20	.15	.10	.10	.10	.10
	D	.25	.20	.15	.10	.10	.10
	E	.30	.25	.20	.15	.10	.10
	F	.40	.30	.20	.15	.10	.10

building and area sources, only when ISW(16) equals "1". This card group is omitted from the input data if ISW(16) equals "0". The program reads NSPEED values from NSTBLE (1 through NSTBLE) data cards in this group. No default values are provided for SIGEPL and if used all values must be punched. Card Group 15 is the median wind speed for each wind speed category (UBAR) and there are NSPEED values read from one data card. The default values for UBAR are shown at the top of Table 4-5. Card Group 16 gives the wind speed power law exponent (P) as a function of wind-speed category and stability or time-of-day category. There are NSPEED values read from NSTBLE data cards (1 through NSTBLE). The default values for P are shown in Table 4-5. Card Group 17, the last of the meteorological input card groups, gives the median wind direction for each wind direction category (THETA). There are 8 values read per data card in this group up to a maximum of NSCTOR (normally 16, 2 cards) values. If the first two values of this array are not punched or both set equal to "0", the program will default THETA to the standard 16 wind directions (0, 22.5, 45, ..., 337.5).

The last card groups in the input data deck, Card Groups 18 through 18c, consist of source-related information. These card groups are omitted from the input deck if the parameter NSOURC equals zero. Card Group 18 (SFMT) provides for an optional input format for Card Group 18a. Card Group 18 (SFMT) is read by the program only if the option ISW(12) equals "1", otherwise it is omitted from the input deck. Card Groups 18a, 18b and 18c, depending on DISP and NVS1, are read as an ordered set by the program for each source, 1 to NSOURC. Card Group 18a contains the primary source information including NUMSQ1, TYPE1, DISP, Q1, DX1, DY1, H1, HS1, TS1, or S11, VOL1 or S21, RDS1 and NVS1. If the parameter DISP is not punched or is "0", the user must punch all of the parameters on this card or accept the default value (if any) of any parameter not set or punched "0". Also, Card Group 18b is not read if DISP equals "0". If the parameter DISP is set to a value of "1", only the parameters NUMSQ1 and Q1 are read from this card and Card Groups 18b and 18c are not read. If DISP equals "2", only NUMSQ1 is read from the card and Card Groups 18b and 18c are not read. If DISP equals "3", the program treats this card as if DISP equaled "0", but ignores Q1 from this card and reads QSS1 in Card Group 18b. Card Group 18b consists of NSTBLE*NSEASN data cards (read only if DISP equals "3"). The user must punch NSPEED values on each data card, 1 to NSTBLE, and there are NSEASN sets of these cards read (1 through NSEASN). The last card group, Card Group 18c, is read only if the preceding Card Group 18a contained NVS1 greater than "0". This card group consists of two arrays of a maximum of 20 values each. The first array gives the settling velocity for each particulate category used in the calculation of concentration with gravitational settling and dry deposition occurring. The second array gives the mass fraction of each particulate category. The last settling velocity punched is immediately followed by the first mass fraction value on the punched cards. The user should remember that this program is not designed to calculate concentration with deposition occurring with terrain elevation data. Also, the program assumes that all particulates that reach the surface through the combined processes of gravitational settling and atmospheric turbulence are retained at the surface.

b. Tape Input Requirements. The LONGZ program accepts an input source/concentration inventory tape previously created by the LONGZ program. This tape is a binary tape, UNIVAC FORTRAN written using the NTRAN I/O routines, that was created as an output tape in a previous run of the LONGZ program. This tape contains all of the program options that affect how the model concentration calculations were performed, all of the receptor and elevation data, all of the meteorological data, all of the source input data and the results of the seasonal (annual) concentration calculations at each receptor point. The program reads the data from the FORTRAN logical unit number(s) specified by NINFL. The tape data are read only if option ISW(1) equals "1". *The input tape requires the user to omit specified data card groups from the input deck and makes the input of some parameter values unnecessary.* The omitted Card Groups and unnecessary parameters are indicated by a *,

, or * in the Card Group and Parameter Name columns of Table 4-4. The format and exact contents of the input tape are discussed in Section 4.2.4b below.

4.2.4 Program Output Data Description

The LONGZ program generates several categories of printed output and an optional output source/concentration inventory tape. The following paragraphs describe the format and content of both forms of program output.

a. Printed Output. The LONGZ program generates 7 categories of printed output, 4 of which are tables of average ground-level concentration. All program printed output is optional except warning and error messages. The printed output categories are:

- Input Source Data
- Input Data Other than Source Data
- Seasonal Concentrations from Individual Sources
- Seasonal Concentrations from Combined Sources
- Annual Concentrations from Individual Sources
- Annual Concentrations from Combined Sources
- Warning and Error Messages

The first line of each page of output contains the run title (TITLE) and page number followed by the major heading of the type or category of output table.

The first category of printed output is the input card data except for the source data. This output is optional and is selected by the option parameter ISW(5). Figure 4-2 shows an example of the printed input data. The example output shown in this section is output generated from an example problem given in Section 2.6. Figure 4-3 shows an example of the source input data table. This example shows each input source

```
                    EXAMPLE LONG TERM PROBLEM                                                          DATE 040679, PAGE    1

                                              TABLE    1

                           *-* PROGRAM INPUT CONTROL AND METEOROLOGICAL PARAMETERS *-*
NUMBER OF SOURCE INPUT CARDS                                  (NSOURC) =      6
NUMBER OF X GRID COORDINATES                                  (NXPNTS) =     19
NUMBER OF Y GRID COORDINATES                                  (NYPNTS) =     19
NUMBER OF SEASONS (IF 1 ANNUAL ASSUMED)                       (NSEASN) =      4
NUMBER OF WIND SPEED CATEGORIES                               (NSPEED) =      6
NUMBER OF STABILITY CATEGORIES                                (NSTBLE) =      5
NUMBER OF WIND DIRECTION (SECTOR) CATEGORIES                  (NSCTOR) =     16
NUMBER OF CONCENTRATION REPORTS (SOURCE COMBINATIONS)(NGROUP) =      5
LAST TAPE INPUT SOURCE                                        (NSTOP  ) =  999999
NUMBER OF DISCRETE X,Y POINTS                                 (NXWYPT) =     20
TOTAL NUMBER OF SOURCES IN INVENTORY                                   =      6
IS TAPE INPUT USED (0 IS NO, NOT 0 IS YES)                    (ISW(1)) = 0
IS TAPE OUTPUT USED                                           (ISW(2)) = 0
IS OUTPUT TAPE SOURCE INVENTORY LISTING PRODUCED              (ISW(2)) = 0
ARE CONCENTRATION REPORTS ON A SEASONAL BASIS                 (ISW(3)) = 1
ARE CONCENTRATION REPORTS ON AN ANNUAL BASIS                  (ISW(4)) = 1
IS AN INPUT CARD SOURCE INVENTORY LISTING PRODUCED            (ISW(6)) = 1
IS AN INPUT TAPE SOURCE INVENTORY LISTING PRODUCED            (ISW(7)) = 0
ARE TERRAIN HEIGHTS INPUT                                     (ISW(8)) = 0
IS UBAR TERRAIN FOLLOWING                                     (ISW(9)) = 0
IS THE FORMAT FOR FREE (CARD GROUP 8A) READ                   (ISW(11))= 0
IS THE FORMAT FOR SOURCE CARDS (CARD GROUP 10A) READ (ISW(12))= 0
GRID SYSTEM IS IN CARTESIAN (=0) OR POLAR (=1) COORDS(ISW(13))= 0
DISCRETE POINTS ARE CARTESIAN (=0) OR POLAR (=1)      (ISW(14))= 0
SOURCE COORDINATES ARE CARTESIAN (=0) OR POLAR (=1)   (ISW(15))= 0
CONCENTRATION UNITS CONVERSION FACTOR,                                 =  .10000000+07
ACCELERATION OF GRAVITY (G METERS/SEC**2) =   9.8000
HEIGHT OF MEASUREMENT OF WIND SPEED (ZR METERS) =  6.096
ENTRAINMENT PARAMETER FOR AN UNSTABLE ATMOSPHERE (GAMMA1) = .600
ENTRAINMENT PARAMETER FOR A STABLE ATMOSPHERE (GAMMA2) = .660
ANGULAR DISPLACEMENT OF GRID SYSTEM FROM TRUE NORTH (ROTATE DEGREES) =    .000
DECAY COEFFICIENT     (DECAY) =   .00000000
ELEVATION OF WEATHER STATION (HA METERS =       .00
X ORIGIN OF POLAR COORDINATES (UTMX METERS) =         .00
Y ORIGIN OF POLAR COORDINATES (UTMY METERS) =         .00
          *-* COORDINATE SYSTEM X AXIS (METERS) *-*

- 30000000+04,  -.20000000+04,  -.15000000+04,  -.12000000+04,  -.10000000+04,  -.80000000+03,  -.60000000+03,  -.40000000+03,
- 20000000+03,   .00000000   ,   .20000000+03,   .40000000+03,   .60000000+03,   .80000000+03,   .10000000+04,   .12000000+04,
  15000000+04,   .20000000+04,   .30000000+04,
          *-* COORDINATE SYSTEM Y AXIS (METERS) *-*

- 30000000+04,  -.20000000+04,  -.15000000+04,  -.12000000+04,  -.10000000+04,  -.80000000+03,  -.60000000+03,  -.40000000+03,
- 20(00000+03,   .00000000   ,   .20000000+03,   .40000000+03,   .60000000+03,   .80000000+03,   .10000000+04,   .12000000+04,
  15000000+04,   .20000000+04,   .30000000+04,
          *-* COORDINATES OF DISCRETE POINTS (METERS,METERS) *-*

(X,Y) = (   -800 0,     700.0), (   -600.0,     700.0), (   -400.0,     700.0), (   -200.0,     700.0), (       .0,     700.0),
(X,Y) = (    200 0,     700.0), (    400.0,     700.0), (    600.0,     700.0), (    800.0,     700 0), (    800.0,     500.0),
(X,Y) = (    800 0,     300.0), (    800.0,     100.0), (    800.0,    -100.0), (    800.0,    -300.0), (    800.0,    -500.0),
(X,Y) = (    600 0,    -500.0), (    400.0,    -500.0), (    200.0,    -500.0), (       .0,    -500 0), (   -200.0,    -500.0),
(X,Y) = (   -400 0,    -500.0), (   -600.0,    -500.0), (   -800.0,    -500.0), (   -800.0,    -300.0), (   -800.0,    -100.0),
(X,Y) = (   -800 0,     100.0), (   -800.0,     300.0), (   -800.0,     500.0), (
```

FIGURE 4-2. Example listing of input data for the calculation of seasonal and annual ground-level concentration.

```
                    EXAMPLE LONG TERM PROBLEM                                                DATE 040679, PAGE    2

                                                TABLE    1 (CONT)

                                   *-* PROGRAM INPUT CONTROL AND METEOROLOGICAL PARAMETERS *-*

                              *-* AMBIENT AIR TEMPERATURE (TA DEGREES KELVIN) *-*

                  STABILITY  STABILITY  STABILITY  STABILITY  STABILITY  STABILITY
                  CATEGORY 1 CATEGORY 2 CATEGORY 3 CATEGORY 4 CATEGORY 5 CATEGORY 6
         SEASON  1   273.2000   273.2000   273.2000   271.2000   269.7000
         SEASON  2   287.0000   287.0000   287.0000   283.7000   280.3000
         SEASON  3   298.3000   298.3000   298.3000   294.4000   290.7000
         SEASON  4   289.5000   289.5000   289.5000   286.3000   282.4000
                                   *-* MIXING LAYER DEPTH (HM METERS) *-*

                                                      SEASON 1
                          WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                          CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
STABILITY CATEGORY 1     .500000+03   .650000+03   .650000+03   .650000+03   .650000+03   .650000+03
STABILITY CATEGORY 2     .500000+03   .650000+03   .710000+03   .710000+03   .710000+03   .710000+03
STABILITY CATEGORY 3     .500000+03   .650000+03   .710000+03   .710000+03   .710000+03   .710000+03
STABILITY CATEGORY 4     .320000+03   .470000+03   .670000+03   .710000+03   .710000+03   .710000+03
STABILITY CATEGORY 5     .140000+03   .290000+03   .630000+03   .630000+03   .630000+03   .630000+03
                                                      SEASON 2
                          WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                          CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
STABILITY CATEGORY 1     .153000+04   .153000+04   .153000+04   .153000+04   .153000+04   .153000+04
STABILITY CATEGORY 2     .153000+04   .153000+04   .153000+04   .153000+04   .153000+04   .153000+04
STABILITY CATEGORY 3     .153000+04   .153000+04   .153000+04   .153000+04   .153000+04   .153000+04
STABILITY CATEGORY 4     .825000+03   .920000+03   .103000+04   .141500+04   .153000+04   .153000+04
STABILITY CATEGORY 5     .120000+03   .310000+03   .530000+03   .530000+03   .530000+03   .530000+03
                                                      SEASON 3
                          WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                          CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
STABILITY CATEGORY 1     .173000+04   .173000+04   .173000+04   .173000+04   .173000+04   .173000+04
STABILITY CATEGORY 2     .173000+04   .173000+04   .173000+04   .173000+04   .173000+04   .173000+04
STABILITY CATEGORY 3     .173000+04   .173000+04   .173000+04   .173000+04   .173000+04   .173000+04
STABILITY CATEGORY 4     .960000+03   .102500+04   .123500+04   .129500+04   .129500+04   .129500+04
STABILITY CATEGORY 5     .190000+03   .320000+03   .740000+03   .740000+03   .740000+03   .740000+03
                                                      SEASON 4
                          WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                          CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
STABILITY CATEGORY 1     .123000+04   .123000+04   .123000+04   .123000+04   .123000+04   .123000+04
STABILITY CATEGORY 2     .123000+04   .123000+04   .123000+04   .123000+04   .123000+04   .123000+04
STABILITY CATEGORY 3     .123000+04   .123000+04   .123000+04   .123000+04   .123000+04   .123000+04
STABILITY CATEGORY 4     .685000+03   .740000+03   .970000+03   .119000+04   .123000+04   .123000+04
STABILITY CATEGORY 5     .140000+03   .250000+03   .710000+03   .710000+03   .710000+03   .710000+03
```

FIGURE 4-2.   (Continued)

```
                         EXAMPLE LONG TERM PROBLEM                                                  DATE 040679, PAGE    3
                                              TABLE    1 (CONT)
                          *-* PROGRAM INPUT CONTROL AND METEOROLOGICAL PARAMETERS *-*
                 *-* FREQUENCY OF OCCURRENCE OF WIND SPEED,DIRECTION AND STABILITY *-*
                                                  SEASON 1
                                            STABILITY CATEGORY 1

                     WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                     CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
  DIRECTION       (   .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
(PHI DEGREES)
       .000        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
     22.500        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
     45.000        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
     67.500        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
     90.000        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
    112.500        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
    135.000        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
    157.500        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
    180.000        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
    202.500        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
    225.000        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
    247.500        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
    270.000        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
    292.500        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
    315.000        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
    337.500        .00002860    .00000000    .00000000    .00000000    .00000000    .00000000
                                                  SEASON 1
                                            STABILITY CATEGORY 2

                     WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                     CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
  DIRECTION       (   .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
(PHI DEGREES)
       .000        .00000000    .00000000    .00000000    .00000000    .00000000    .00000000
     22.500        .00022890    .00045790    .00000000    .00000000    .00000000    .00000000
     45.000        .00000000    .00000000    .00000000    .00000000    .00000000    .00000000
     67.500        .00000000    .00000000    .00000000    .00000000    .00000000    .00000000
     90.000        .00000000    .00000000    .00000000    .00000000    .00000000    .00000000
    112.500        .00000000    .00000000    .00000000    .00000000    .00000000    .00000000
    135.000        .00000000    .00000000    .00000000    .00000000    .00000000    .00000000
    157.500        .00000000    .00000000    .00000000    .00000000    .00000000    .00000000
    180.000        .00000000    .00000000    .00000000    .00000000    .00000000    .00000000
    202.500        .00000000    .00000000    .00000000    .00000000    .00000000    .00000000
    225.000        .00000000    .00000000    .00000000    .00000000    .00000000    .00000000
    247.500        .00068680    .00000000    .00000000    .00000000    .00000000    .00000000
    270.000        .00068680    .00000000    .00000000    .00000000    .00000000    .00000000
    292.500        .00022890    .00045790    .00000000    .00000000    .00000000    .00000000
    315.000        .00000000    .00000000    .00000000    .00000000    .00000000    .00000000
    337.500        .00000000    .00000000    .00000000    .00000000    .00000000    .00000000
```

FIGURE 4-2. (Continued)

```
                          EXAMPLE LONG TERM PROBLEM                                       DATE 040679, PAGE    4

                                        TABLE    1 (CONT)

                         *-* PROGRAM INPUT CONTROL AND METEOROLOGICAL PARAMETERS *-*

                  *-* FREQUENCY OF OCCURRENCE OF WIND SPEED,DIRECTION AND STABILITY *-*
                                            SEASON 1
                                      STABILITY CATEGORY 3

                 WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                 CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
   DIRECTION   (   .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
 (PHI DEGREES)
          .000    .00008720    .00045790    .00091580    .00000000    .00000000    .00000000
        22.500    .00000000    .00000000    .00045790    .00000000    .00000000    .00000000
        45.000    .00000000    .00000000    .00045790    .00000000    .00000000    .00000000
        67.500    .00109020    .00000000    .00045790    .00000000    .00000000    .00000000
        90.000    .00063230    .00045790    .00000000    .00000000    .00000000    .00000000
       112.500    .00008720    .00045790    .00000000    .00000000    .00000000    .00000000
       135.000    .00008720    .00045790    .00091580    .00000000    .00000000    .00000000
       157.500    .00109020    .00000000    .00045790    .00000000    .00000000    .00000000
       180.000    .00017440    .00091580    .00228940    .00000000    .00000000    .00000000
       202.500    .00000000    .00000000    .00091580    .00000000    .00000000    .00000000
       225.000    .00000000    .00000000    .00228940    .00000000    .00000000    .00000000
       247.500    .00008720    .00045790    .00503660    .00000000    .00000000    .00000000
       270.000    .00043610    .00228940    .00366300    .00000000    .00000000    .00000000
       292.500    .00017440    .00091580    .00228940    .00000000    .00000000    .00000000
       315.000    .00063230    .00045790    .00091580    .00000000    .00000000    .00000000
       337.500    .00000000    .00000000    .00137360    .00000000    .00000000    .00000000
                                            SEASON 1
                                      STABILITY CATEGORY 4

                 WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                 CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
   DIRECTION   (   .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
 (PHI DEGREES)
          .000    .00178990    .00549449    .02426738    .00824179    .00091580    .00000000
        22.500    .00248360    .00091580    .00412090    .00000000    .00000000    .00000000
        45.000    .00008330    .00137360    .00274730    .00000000    .00000000    .00000000
        67.500    .00011100    .00183150    .00274730    .00000000    .00000000    .00000000
        90.000    .00141530    .00732599    .00641029    .00000000    .00000000    .00000000
       112.500    .00181760    .00595239    .00549449    .00000000    .00000000    .00000000
       135.000    .00323290    .01327839    .01465199    .00412090    .00000000    .00000000
       157.500    .00049950    .00824179    .02197798    .00183150    .00000000    .00000000
       180.000    .00314960    .01190479    .03296697    .01144689    .00183150    .00000000
       202.500    .00073540    .00412090    .02014648    .01282049    .00091580    .00000000
       225.000    .00073540    .00412090    .03113547    .03754577    .00686809    .00045790
       247.500    .00027750    .00457880    .03205127    .04532966    .00824179    .00000000
       270.000    .00070760    .00366300    .04349816    .07417573    .01419409    .00320510
       292.500    .00092960    .00732599    .01877288    .03525637    .01785708    .00091580
       315.000    .00049950    .00824179    .02335158    .02335158    .00961539    .00137360
       337.500    .00030530    .00503660    .02747247    .02014648    .00183150    .00000000
```

FIGURE 4-2. (Continued)

```
                         EXAMPLE LONG TERM PROBLEM                                           DATE 040679, PAGE    5

                                         TABLE    1 (CONT)

                         *-* PROGRAM INPUT CONTROL AND METEOROLOGICAL PARAMETERS *-*

               *-* FREQUENCY OF OCCURRENCE OF WIND SPEED,DIRECTION AND STABILITY *-*
                                          SEASON 1
                                    STABILITY CATEGORY 5

                    WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                    CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
   DIRECTION     (    .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
 (PHI DEGREES)
        .000        .00040060   .00366310   .00412090   .00000000   .00000000   .00000000
      22.500        .00065820   .00091580   .00045790   .00000000   .00000000   .00000000
      45.000        .00040060   .00457980   .00000000   .00000000   .00000000   .00000000
      67.500        .00059140   .00045790   .00045790   .00000000   .00000000   .00000000
      90.000        .00283310   .01327939   .00000000   .00000000   .00000000   .00000000
     112.500        .00197460   .00549459   .00000000   .00000000   .00000000   .00000000
     135.000        .00527510   .01739920   .00045790   .00000000   .00000000   .00000000
     157.500        .00422580   .01648348   .00274730   .00000000   .00000000   .00000000
     180.000        .00455010   .01877288   .00595239   .00000000   .00000000   .00000000
     202.500        .00139270   .00732599   .00549449   .00000000   .00000000   .00000000
     225.000        .00066770   .00641029   .00915749   .00000000   .00000000   .00000000
     247.500        .00205090   .00961339   .00686809   .00000000   .00000000   .00000000
     270.000        .00171700   .00549459   .00732599   .00000000   .00000000   .00000000
     292.500        .00079170   .00320510   .00228940   .00000000   .00000000   .00000000
     315.000        .00033390   .00320520   .00274730   .00000000   .00000000   .00000000
     337.500        .00006680   .00137370   .00274730   .00000000   .00000000   .00000000
                                          SEASON 2
                                    STABILITY CATEGORY 1

                    WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                    CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
   DIRECTION     (    .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
 (PHI DEGREES)
        .000        .00010060   .00045290   .00000000   .00000000   .00000000   .00000000
      22.500        .00055350   .00000000   .00000000   .00000000   .00000000   .00000000
      45.000        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
      67.500        .00020130   .00090580   .00000000   .00000000   .00000000   .00000000
      90.000        .00020130   .00090580   .00000000   .00000000   .00000000   .00000000
     112.500        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
     135.000        .00010060   .00045290   .00000000   .00000000   .00000000   .00000000
     157.500        .00010060   .00045290   .00000000   .00000000   .00000000   .00000000
     180.000        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
     202.500        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
     225.000        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
     247.500        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
     270.000        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
     292.500        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
     315.000        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
     337.500        .00055350   .00000000   .00000000   .00000000   .00000000   .00000000
```

FIGURE 4-2. (Continued)

```
                              EXAMPLE LONG TERM PROBLEM                                        DATE 040679, PAGE    6

                                             TABLE    1 (CONT)

                              *-* PROGRAM INPUT CONTROL AND METEOROLOGICAL PARAMETERS *-*

                    *-* FREQUENCY OF OCCURRENCE OF WIND SPEED,DIRECTION AND STABILITY *-*
                                             SEASON 2
                                        STABILITY CATEGORY 2

                  WIND SPEED  WIND SPFED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                  CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
    DIRECTION    (  .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
  (PHI DEGREES)
         .000      .00053380   .00181160   .00317030   .00000000   .00000000   .00000000
       22.500      .00003230   .00090580   .00090580   .00000000   .00000000   .00000000
       45.000      .00004850   .00135870   .00000000   .00000000   .00000000   .00000000
       67.500      .00004850   .00135870   .00090580   .00000000   .00000000   .00000000
       90.000      .00003230   .00090580   .00000000   .00000000   .00000000   .00000000
      112.500      .00050140   .00090580   .00045290   .00000000   .00000000   .00000000
      135.000      .00148810   .00226450   .00000000   .00000000   .00000000   .00000000
      157.500      .00143960   .00090580   .00090580   .00000000   .00000000   .00000000
      180.000      .00009700   .00271740   .00135870   .00000000   .00000000   .00000000
      202.500      .00048520   .00045290   .00045290   .00000000   .00000000   .00000000
      225.000      .00001620   .00045290   .00045290   .00000000   .00000000   .00000000
      247.500      .00003230   .00090580   .00090580   .00000000   .00000000   .00000000
      270.000      .00008090   .00226450   .00090580   .00000000   .00000000   .00000000
      292.500      .00003230   .00090580   .00181160   .00000000   .00000000   .00000000
      315.000      .00006470   .00181160   .00045290   .00000000   .00000000   .00000000
      337.500      .00004850   .00135870   .00090580   .00000000   .00000000   .00000000
                                             SEASON 2
                                        STABILITY CATEGORY 3

                  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                  CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
    DIRECTION    (  .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
  (PHI DEGREES)
         .000      .00029640   .00271740   .00724640   .00000000   .00000000   .00000000
       22.500      .00000000   .00000000   .00181160   .00000000   .00000000   .00000000
       45.000      .00014820   .00135870   .00045290   .00000000   .00000000   .00000000
       67.500      .00060110   .00090580   .00045290   .00000000   .00000000   .00000000
       90.000      .00039530   .00362320   .00135870   .00000000   .00000000   .00000000
      112.500      .00113280   .00135870   .00362320   .00000000   .00000000   .00000000
      135.000      .00089760   .00362320   .00271740   .00045290   .00000000   .00000000
      157.500      .00009880   .00090580   .00317030   .00000000   .00000000   .00000000
      180.000      .00113280   .00135870   .00543480   .00000000   .00000000   .00000000
      202.500      .00055170   .00045290   .00226450   .00000000   .00000000   .00000000
      225.000      .00065050   .00135870   .00271740   .00000000   .00045290   .00000000
      247.500      .00004940   .00045290   .00815220   .00045290   .00090580   .00000000
      270.000      .00014820   .00135870   .00996379   .00181160   .00000000   .00000000
      292.500      .00014820   .00135870   .00724640   .00045290   .00000000   .00000000
      315.000      .00004940   .00045290   .00452900   .00045290   .00000000   .00000000
      337.500      .00000000   .00000000   .00452900   .00181160   .00090580   .00000000
```

FIGURE 4-2. (Continued)

```
                    EXAMPLE LONG TERM PROBLEM                                           DATE 040679, PAGE    7

                                           TABLE    1 (CONT)

                         *-* PROGRAM INPUT CONTROL AND METEOROLOGICAL PARAMETERS *-*

               *-* FREQUENCY OF OCCURRENCE OF WIND SPEED,DIRECTION AND STABILITY *-*
                                        SEASON 2
                                  STABILITY CATEGORY 4

                 WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                 CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
  DIRECTION    (   .7300MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
(PHI DEGREES)
       .000     .00017030   .00498190   .02219199   .01947459   .00135870   .00000000
     22.500     .00004650   .00135870   .00679350   .00090580   .00000000   .00000000
     45.000     .00009290   .00271740   .00271740   .00000000   .00000000   .00000000
     67.500     .00006190   .00181160   .00588770   .00045290   .00000000   .00000000
     90.000     .00012390   .00362320   .01403989   .00045290   .00000000   .00000000
    112.500     .00007740   .00226450   .01086959   .00271740   .00000000   .00000000
    135.000     .00062320   .00452900   .01721009   .00271740   .00000000   .00000000
    157.500     .00057680   .00317030   .00996379   .00271740   .00045290   .00000000
    180.000     .00013940   .00407610   .01630429   .01268119   .00181160   .00000000
    202.500     .00048390   .00045290   .01358699   .01222029   .00181160   .00000000
    225.000     .00010840   .00317030   .03079708   .02264489   .00181160   .00000000
    247.500     .00012390   .00362320   .02355069   .03849638   .00498190   .00181160
    270.000     .00012390   .00362320   .02490939   .04347828   .01403989   .00407610
    292.500     .00062320   .00452900   .01947459   .02853258   .00860510   .00045290
    315.000     .00107610   .00407610   .01947459   .03759058   .00905800   .00181160
    337.500     .00007740   .00226450   .01721009   .01856879   .00317030   .00000000
                                        SEASON 2
                                  STABILITY CATEGORY 5

                 WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                 CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
  DIRECTION    (   .7300MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
(PHI DEGREES)
       .000     .00081560   .00452900   .01539859   .00000000   .00000000   .00000000
     22.500     .00229080   .00226450   .00181160   .00000000   .00000000   .00000000
     45.000     .00377920   .00498190   .00000000   .00000000   .00000000   .00000000
     67.500     .00058260   .00498190   .00135870   .00000000   .00000000   .00000000
     90.000     .00539720   .01403989   .00045290   .00000000   .00000000   .00000000
    112.500     .00434860   .00769930   .00045290   .00000000   .00000000   .00000000
    135.000     .00570730   .00679350   .00000000   .00000000   .00000000   .00000000
    157.500     .00503450   .00905800   .00181160   .00000000   .00000000   .00000000
    180.000     .00720880   .01494569   .00679350   .00000000   .00000000   .00000000
    202.500     .00068590   .00588770   .00000000   .00000000   .00000000   .00000000
    225.000     .00274370   .00769930   .00000000   .00000000   .00000000   .00000000
    247.500     .00207090   .00860510   .00543480   .00000000   .00000000   .00000000
    270.000     .00748130   .01449279   .00543480   .00000000   .00000000   .00000000
    292.500     .00519050   .01313409   .00362320   .00000000   .00000000   .00000000
    315.000     .00573360   .00724640   .00679350   .00000000   .00000000   .00000000
    337.500     .00207090   .00407610   .00452900   .00000000   .00000000   .00000000
```

FIGURE 4-2. (Continued)

```
                         EXAMPLE LONG TERM PROBLEM                                                DATE 040679, PAGE    8

                                               TABLE    1 (CONT)

                         *-* PROGRAM INPUT CONTROL AND METEOROLOGICAL PARAMETERS *-*

              *-* FREQUENCY OF OCCURRENCE OF WIND SPEED,DIRECTION AND STABILITY *-*
                                          SEASON 3
                                    STABILITY CATEGORY 1

                   WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                   CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
   DIRECTION     (   .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
 (PHI DEGREES)
        .000        .00003940   .00090580   .00000000   .00000000   .00000000   .00000000
      22.500        .00051200   .00090580   .00000000   .00000000   .00000000   .00000000
      45.000        .00003940   .00090580   .00000000   .00000000   .00000000   .00000000
      67.500        .00001970   .00045290   .00000000   .00000000   .00000000   .00000000
      90.000        .00001970   .00045290   .00000000   .00000000   .00000000   .00000000
     112.500        .00047260   .00000000   .00000000   .00000000   .00000000   .00000000
     135.000        .00001970   .00045290   .00000000   .00000000   .00000000   .00000000
     157.500        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
     180.000        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
     202.500        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
     225.000        .00009850   .00226450   .00000000   .00000000   .00000000   .00000000
     247.500        .00001970   .00045290   .00000000   .00000000   .00000000   .00000000
     270.000        .00005910   .00135970   .00000000   .00000000   .00000000   .00000000
     292.500        .00001970   .00045290   .00000000   .00000000   .00000000   .00000000
     315.000        .00003940   .00090580   .00000000   .00000000   .00000000   .00000000
     337.500        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
                                          SEASON 3
                                    STABILITY CATEGORY 2

                   WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                   CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
   DIRECTION     (   .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
 (PHI DEGREES)
        .000        .00157830   .00588769   .00407609   .00000000   .00000000   .00000000
      22.500        .00050780   .00135870   .00045290   .00000000   .00000000   .00000000
      45.000        .00050780   .00135870   .00045290   .00000000   .00000000   .00000000
      67.500        .00100190   .00226450   .00135870   .00000000   .00000000   .00000000
      90.000        .00009610   .00317029   .00090580   .00000000   .00000000   .00000000
     112.500        .00056270   .00317029   .00226450   .00000000   .00000000   .00000000
     135.000        .00104300   .00362319   .00090580   .00000000   .00000000   .00000000
     157.500        .00247039   .00452899   .00271739   .00000000   .00000000   .00000000
     180.000        .00344479   .00588769   .00317029   .00000000   .00000000   .00000000
     202.500        .00050780   .00135970   .00090580   .00000000   .00000000   .00000000
     225.000        .00005490   .00181160   .00135870   .00000000   .00000000   .00000000
     247.500        .00057640   .00362319   .00317029   .00000000   .00000000   .00000000
     270.000        .00057640   .00362319   .00181160   .00000000   .00000000   .00000000
     292.500        .00005490   .00181160   .00090580   .00000000   .00000000   .00000000
     315.000        .00008230   .00271739   .00317029   .00000000   .00000000   .00000000
     337.500        .00006860   .00226450   .00135870   .00000000   .00000000   .00000000
```

FIGURE 4-2. (Continued)

```
                    EXAMPLE LONG TERM PROBLEM                                                        DATE 040673, PAGE    9

                                          TABLE    1 (CONT)

                     *-* PROGRAM INPUT CONTROL AND METEOROLOGICAL PARAMETERS *-*

            *-* FREQUENCY OF OCCURRENCE OF WIND SPEED,DIRECTION AND STABILITY *-*
                                          SEASON 3
                                     STABILITY CATEGORY 3

                   WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                   CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
    DIRECTION    (   .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
  (PHI DEGREES)
        .000       .00028820   .00317029   .00498189   .00000000   .00000000   .00000000
      22.500       .00074110   .00271739   .00317029   .00000000   .00000000   .00000000
      45.000       .00012350   .00135870   .00090580   .00000000   .00000000   .00000000
      67.500       .00008230   .00090580   .00317029   .00045290   .00000000   .00000000
      90.000       .00065880   .00181160   .00724638   .00181160   .00000000   .00000000
     112.500       .00065880   .00181160   .00090580   .00000000   .00000000   .00000000
     135.000       .00074110   .00271739   .00135870   .00000000   .00000000   .00000000
     157.500       .00189390   .00452899   .00135870   .00000000   .00000000   .00000000
     180.000       .00135870   .00407609   .00634059   .00000000   .00000000   .00000000
     202.500       .00000000   .00000000   .00407609   .00000000   .00000000   .00000000
     225.000       .00016470   .00181160   .00588769   .00090580   .00000000   .00000000
     247.500       .00041170   .00452899   .00769928   .00271739   .00000000   .00000000
     270.000       .00139990   .00452899   .01222827   .00362319   .00000000   .00000000
     292.500       .00020590   .00226450   .00724638   .00317029   .00045290   .00045290
     315.000       .00057640   .00090580   .00724638   .00045290   .00045290   .00000000
     337.500       .00065880   .00181160   .00498189   .00045290   .00000000   .00000000
                                          SEASON 3
                                     STABILITY CATEGORY 4

                   WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                   CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
    DIRECTION    (   .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
  (PHI DEGREES)
        .000       .00122360   .00815218   .01992746   .00452899   .00000000   .00090580
      22.500       .00014300   .00407609   .00271739   .00000000   .00000000   .00000000
      45.000       .00020660   .00588769   .00226450   .00000000   .00000000   .00000000
      67.500       .00027020   .00769928   .00679349   .00000000   .00000000   .00000000
      90.000       .00153350   .00362319   .00634059   .00090580   .00000000   .00000000
     112.500       .00054820   .00226450   .00181160   .00045290   .00000000   .00000000
     135.000       .00117590   .00679349   .00226450   .00000000   .00000000   .00000000
     157.500       .00167650   .00769928   .00588769   .00000000   .00000000   .00000000
     180.000       .00320999   .01132248   .01222827   .00135870   .00000000   .00000000
     202.500       .00158120   .00498189   .01132248   .00317029   .00000000   .00000000
     225.000       .00044500   .01268117   .02536225   .01630427   .00000000   .00000000
     247.500       .00174010   .00951088   .03577892   .01358697   .00000000   .00000000
     270.000       .00141430   .01358697   .02219195   .01313407   .00090580   .00000000
     292.500       .00022250   .00634059   .00951088   .00679349   .00135870   .00000000
     315.000       .00072300   .00724638   .01736296   .00452899   .00045290   .00000000
     337.500       .00064360   .00498189   .01947456   .01313407   .00000000   .00000000
```

FIGURE 4-2. (Continued)

```
                    EXAMPLE LONG TERM PROBLEM                                                      DATE 040679, PAGE   10

                                       TABLE    I (CONT)

                      *-* PROGRAM INPUT CONTROL AND METEOROLOGICAL PARAMETERS *-*

                 *-* FREQUENCY OF OCCURRENCE OF WIND SPEED,DIRECTION AND STABILITY *-*
                                            SEASON 3
                                      STABILITY CATEGORY 5

                 WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                 CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
  DIRECTION    (   .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
 (PHI DEGREES)
      .000        .00757648   .01313407   .00815218   .00000000   .00000000   .00000000
    22.500        .00492049   .00634059   .00000000   .00000000   .00000000   .00000000
    45.000        .00169650   .00226450   .00000000   .00000000   .00000000   .00000000
    67.500        .00433709   .00498189   .00000000   .00000000   .00000000   .00000000
    90.000        .00971048   .01132248   .00135870   .00000000   .00000000   .00000000
   112.500        .00346969   .00271739   .00045290   .00000000   .00000000   .00000000
   135.000        .01440827   .01041668   .00045290   .00000000   .00000000   .00000000
   157.500        .01180607   .01041668   .00090580   .00000000   .00000000   .00000000
   180.000        .00867418   .01585147   .00135870   .00000000   .00000000   .00000000
   202.500        .00495889   .01041668   .00135870   .00000000   .00000000   .00000000
   225.000        .00429869   .01041668   .00317029   .00000000   .00000000   .00000000
   247.500        .01153738   .02038046   .00181160   .00000000   .00000000   .00000000
   270.000        .01668816   .01268117   .00407609   .00000000   .00000000   .00000000
   292.500        .01466927   .01403987   .00090580   .00000000   .00000000   .00000000
   315.000        .01087718   .01675726   .00362319   .00000000   .00000000   .00000000
   337.500        .00397629   .00996378   .00588769   .00000000   .00000000   .00000000
                                            SEASON 4
                                      STABILITY CATEGORY 1

                 WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                 CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
  DIRECTION    (   .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
 (PHI DEGREES)
      .000        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
    22.500        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
    45.000        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
    67.500        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
    90.000        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
   112.500        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
   135.000        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
   157.500        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
   180.000        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
   202.500        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
   225.000        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
   247.500        .00091580   .00000000   .00000000   .00000000   .00000000   .00000000
   270.000        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
   292.500        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
   315.000        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
   337.500        .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
```

FIGURE 4-2. (Continued)

```
                    EXAMPLE LONG TERM PROBLEM                                        DATE 040679, PAGE   11

                                    TABLE    1 (CONT)

                  *-* PROGRAM INPUT CONTROL AND METEOROLOGICAL PARAMETERS *-*

            *-* FREQUENCY OF OCCURRENCE OF WIND SPEED,DIRECTION AND STABILITY *-*
                                      SEASON 4
                                STABILITY CATEGORY 2

               WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
               CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
  DIRECTION   (  .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
(PHI DEGREES)
       .000     .00002410   .00045790   .00045790   .00000000   .00000000   .00000000
     22.500     .00050610   .00045790   .00045790   .00000000   .00000000   .00000000
     45.000     .00053020   .00091580   .00091580   .00000000   .00000000   .00000000
     67.500     .00096390   .00000000   .00000000   .00000000   .00000000   .00000000
     90.000     .00007230   .00137360   .00000000   .00000000   .00000000   .00000000
    112.500     .00098800   .00045790   .00000000   .00000000   .00000000   .00000000
    135.000     .00057840   .00183150   .00045790   .00000000   .00000000   .00000000
    157.500     .00050610   .00045790   .00091580   .00000000   .00000000   .00000000
    180.000     .00103620   .00137360   .00091580   .00000000   .00000000   .00000000
    202.500     .00000000   .00000000   .00045790   .00000000   .00000000   .00000000
    225.000     .00050610   .00045790   .00000000   .00000000   .00000000   .00000000
    247.500     .00007230   .00137360   .00091580   .00000000   .00000000   .00000000
    270.000     .00004820   .00091580   .00000000   .00000000   .00000000   .00000000
    292.500     .00007230   .00137360   .00000000   .00000000   .00000000   .00000000
    315.000     .00000000   .00000000   .00000000   .00000000   .00000000   .00000000
    337.500     .00050610   .00045790   .00000000   .00000000   .00000000   .00000000
                                      SEASON 4
                                STABILITY CATEGORY 3

               WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
               CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
  DIRECTION   (  .7500MPS)( 2.5000MPS)( 4.3000MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
(PHI DEGREES)
       .000     .00043380   .00183150   .00193150   .00000000   .00000000   .00000000
     22.500     .00000000   .00000000   .00193150   .00000000   .00000000   .00000000
     45.000     .00010840   .00045790   .00193150   .00000000   .00000000   .00000000
     67.500     .00000000   .00000000   .00045790   .00000000   .00000000   .00000000
     90.000     .00124110   .00045790   .00091580   .00000000   .00000000   .00000000
    112.500     .00021690   .00091580   .00045790   .00000000   .00000000   .00000000
    135.000     .00075910   .00320510   .00274730   .00000000   .00000000   .00000000
    157.500     .00043380   .00183150   .00228940   .00000000   .00000000   .00000000
    180.000     .00054220   .00228940   .00412090   .00000000   .00000000   .00000000
    202.500     .00000000   .00000000   .00274730   .00000000   .00000000   .00000000
    225.000     .00000000   .00000000   .00503659   .00000000   .00000000   .00000000
    247.500     .00010840   .00045790   .00686809   .00000000   .00000000   .00000000
    270.000     .00143390   .00366300   .01007329   .00000000   .00000000   .00000000
    292.500     .00010840   .00045790   .00503659   .00000000   .00000000   .00000000
    315.000     .00010840   .00045790   .00193150   .00000000   .00000000   .00000000
    337.500     .00000000   .00000000   .00193150   .00000000   .00000000   .00000000
```

FIGURE 4-2. (Continued)

```
                      EXAMPLE LONG TERM PROBLEM                                                    DATE 040679, PAGE   12

                                           TABLE    1 (CONT)

                            *-* PROGRAM INPUT CONTROL AND METEOROLOGICAL PARAMETERS *-*

                      *-* FREQUENCY OF OCCURRENCE OF WIND SPEED.DIRECTION AND STABILITY *-*
                                             SEASON 4
                                       STABILITY CATEGORY 4

                 WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                 CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
   DIRECTION    (   .7500MPS)( 2.5000MPS)( 4.3030MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
 (PHI DEGREES)
        .000      .00171560   .01510988   .04349816   .01190479   .00000000   .00000000
      22.500      .00109620   .00778389   .00503659   .00000000   .00000000   .00000000
      45.000      .00067640   .01007329   .00824179   .00045790   .00000000   .00000000
      67.500      .00005700   .00274730   .00356300   .00091580   .00000000   .00000000
      90.000      .00056240   .00457980   .00274730   .00000000   .00000000   .00000000
     112.500      .00051490   .00228940   .00193150   .00045790   .00000000   .00000000
     135.000      .00059090   .00595239   .00732599   .00045790   .00000000   .00000000
     157.500      .00010450   .00503659   .00595239   .00091580   .00000000   .00000000
     180.000      .00152560   .00595239   .01694138   .00183150   .00000000   .00000000
     202.500      .00008550   .00412090   .01053109   .01007329   .00045790   .00000000
     225.000      .00016150   .00778389   .02554097   .01694138   .00137360   .00045790
     247.500      .00006650   .00320510   .03021977   .02747247   .00503659   .00045790
     270.000      .00201200   .00686809   .04258236   .05219775   .00778389   .00045790
     292.500      .00015200   .00732599   .02426738   .02838827   .00320510   .00000000
     315.000      .00154460   .00686809   .01968858   .01785708   .00228940   .00000000
     337.500      .00058140   .00549449   .02060438   .01282049   .00045790   .00000000
                                             SEASON 4
                                       STABILITY CATEGORY 5

                 WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED  WIND SPEED
                 CATEGORY 1  CATEGORY 2  CATEGORY 3  CATEGORY 4  CATEGORY 5  CATEGORY 6
   DIRECTION    (   .7500MPS)( 2.5000MPS)( 4.3030MPS)( 6.8000MPS)( 9.5000MPS)(12.5000MPS)
 (PHI DEGREES)
        .000      .00230130   .00778389   .00824179   .00000000   .00000000   .00000000
      22.500      .00055300   .00412090   .00091580   .00000000   .00000000   .00000000
      45.000      .00459060   .00503659   .00045790   .00000000   .00000000   .00000000
      67.500      .00376410   .00320510   .00000000   .00000000   .00000000   .00000000
      90.000      .00573289   .00457980   .00045790   .00000000   .00000000   .00000000
     112.500      .00514369   .00503659   .00000000   .00000000   .00000000   .00000000
     135.000      .00495929   .00686819   .00137360   .00000000   .00000000   .00000000
     157.500      .00597019   .00549449   .00193150   .00000000   .00000000   .00000000
     180.000      .01011489   .01602558   .00641029   .00000000   .00000000   .00000000
     202.500      .00368680   .01190479   .00356300   .00000000   .00000000   .00000000
     225.000      .00469170   .01053109   .00595239   .00000000   .00000000   .00000000
     247.500      .00873529   .01602558   .01098899   .00000000   .00000000   .00000000
     270.000      .01913559   .03525636   .01648348   .00000000   .00000000   .00000000
     292.500      .00368080   .00915749   .00320510   .00000000   .00000000   .00000000
     315.000      .00662429   .01419419   .00320510   .00000000   .00000000   .00000000
     337.500      .00193260   .00366300   .00457880   .00000000   .00000000   .00000000
```

FIGURE 4-2. (Continued)

```
                                   EXAMPLE LONG TERM PROBLEM                                              DATE 040679, PAGE   13

                                                        TABLE    1 (CONT)

                                 *-* PROGRAM INPUT CONTROL AND METEOROLOGICAL PARAMETERS *-*

        *-* STANDARD DEVIATION OF THE WIND ELEVATION ANGLE FOR ELEVATED POINT OR VOLUME SOURCES (SIGEPU RADIANS) *-*

                           WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                           CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
STABILITY CATEGORY 1      .174500+00   .174500+00   .174500+00   .174500+00   .174500+00   .174500+00
STABILITY CATEGORY 2      .174500+00   .174500+00   .174500+00   .174500+00   .174500+00   .174500+00
STABILITY CATEGORY 3      .108000+00   .108000+00   .108000+00   .108000+00   .174500+00   .174500+00
STABILITY CATEGORY 4      .735000-01   .735000-01   .735000-01   .108000+00   .108000+00   .108000+00
STABILITY CATEGORY 5      .465000-01   .465000-01   .465000-01   .465000-01   .735000-01   .735000-01
        *-* STANDARD DEVIATION OF THE WIND ELEVATION ANGLE FOR AREA OR BUILDING EMISSIONS SOURCES (SIGEPL RADIANS) *-*

                           WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                           CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
STABILITY CATEGORY 1      .174500+00   .174500+00   .174500+00   .174500+00   .174500+00   .174500+00
STABILITY CATEGORY 2      .174500+00   .174500+00   .174500+00   .174500+00   .174500+00   .174500+00
STABILITY CATEGORY 3      .108000+00   .108000+00   .108000+00   .174500+00   .174500+00   .174500+00
STABILITY CATEGORY 4      .735000-01   .735000-01   .735000-01   .108000+00   .108000+00   .108000+00
STABILITY CATEGORY 5      .465000-01   .465000-01   .465000-01   .465000-01   .735000-01   .735000-01
                     *-* VERTICAL POTENTIAL TEMPERATURE GRADIENT (DPDZ DEGREES KELVIN) *-*

                           WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                           CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
STABILITY CATEGORY 1      .000000      .000000      .000000      .000000      .000000      .000000
STABILITY CATEGORY 2      .000000      .000000      .000000      .000000      .000000      .000000
STABILITY CATEGORY 3      .000000      .000000      .000000      .000000      .000000      .000000
STABILITY CATEGORY 4      .150000-01   .100000-01   .500000-02   .000000      .000000      .000000
STABILITY CATEGORY 5      .300000-01   .200000-01   .150000-01   .300000-02   .300000-02   .300000-02
                                                    .000000      .000000      .000000
                                  *-* WIND PROFILE POWER LAW EXPONENT (P) *-*

                           WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED   WIND SPEED
                           CATEGORY 1   CATEGORY 2   CATEGORY 3   CATEGORY 4   CATEGORY 5   CATEGORY 6
STABILITY CATEGORY 1      .100000+00   .100000+00   .100000+00   .100000+00   .100000+00   .100000+00
STABILITY CATEGORY 2      .100000+00   .100000+00   .100000+00   .100000+00   .100000+00   .100000+00
STABILITY CATEGORY 3      .200000+00   .150000+00   .100000+00   .100000+00   .100000+00   .100000+00
STABILITY CATEGORY 4      .250000+00   .200000+00   .100000+00   .100000+00   .100000+00   .100000+00
STABILITY CATEGORY 5      .300000+00   .250000+00   .200000+00   .150000+00   .100000+00   .100000+00
```

FIGURE 4-2. (Continued)

```
                     EXAMPLE LONG TERM PROBLEM                                              DATE 040679, PAGE   14

                                                              TABLE    2

                                                      *-* INPUT SOURCE DATA *-*

C T D SOURCE T      SOURCE STRENGTH (GRAMS/SEC)              X           Y       HEIGHT ELEVATION   IF TYPE=0     IF TYPE=0     STACK
A A I NUMBER Y                                                                    ABOVE     AT     TEMP (DEG K)  VOL. EMISS.   INTERNAL
R P S        P SEASON 1  SEASON 2  SEASON 3  SEASON 4 COORDINATE COORDINATE  GROUND    BASE     IF TYPE=1OR2 RT. M**3/SEC   RADIUS
D E P        E OF ANNUAL                                (METERS)   (METERS)  (METERS) (METERS) LENGTH SHORT   IF TYPE=1OR2  (MTR)
                                                                                               SIDE (METERS) LENGTH LONG
                                                                                                             SIDE (MTRS)
X   0      1 0     3.700     3.700     3.700     3.700   -350.00        .00     60.00      .00      370.000       267.500      1.85
X   0      2 0      .600      .600      .600      .600   -100.00     250.00     30.00      .00      340.000       106.000      1.30
X   0      3 0      .200      .200      .200      .200    200.00     350.00     25.00      .00      590.000        10.800       .54
X   0      4 1      .730      .730      .730      .730   -200.00        .00     15.00      .00      200.000       200.000       .00
X   0      5 1      .730      .730      .730      .730       .00        .00     15.00      .00      200.000       200.000       .00
X   0      6 1      .730      .730      .730      .730    200.00        .00     15.00      .00      200.000       200.000       .00
```

FIGURE 4-3. Example listing of input sources used in the calculation of seasonal and annual ground-level concentration.

listed down the page. The third through sixth category of output tables are concentration tables. Figures 4-4 through 4-7 show an example of each type of output table. These tables are defined by their respective headings and are all optional, depending on the parameters ISW(3) and ISW(4) and NGROUP. Note that, if NGROUP equals "0" or both ISW(3) and ISW(4) equal "0", concentration tables are not printed. The warning and error messages produced by the program are generated by data errors within the LONGZ program and are in general not associated with errors detected by the computer system on which the program is being run. These errors are given in Section 4.2.6 below.

b. Master Tape Inventory Output. The LONGZ program will, on option, generate an output master source/concentration inventory tape. This data tape is written only if the parameter ISW(2) equals "1" or "2" and the data are written to the FORTRAN logical unit specified by NOTFL. The data are written using the UNIVAC 1110 NTRAN binary write routines and tapes must be assigned with the W option to place a write-ring in the output tape. The format and contents of the LONGZ input/output tape are shown in Table 4-6. This table gives the Logical Record, Word Number, Parameter Name and whether the data are in an integer or floating point (real) format. The logical record gives the order the respective data records are written to tape and does not imply the physical (block) length actually on the tape. The physical block length of each tape record is 2000 UNIVAC 1110 words. Records 5 through 9 are repeated on the output tape for as many sources that are processed by the program. Records 6 through 9 represent the seasonal concentration calculations for the seasons winter, spring, summer and fall. However, if only annual meteorology is used by the LONGZ program, only record 6 will occur on the output tape as annual concentration and records 7 through 9 are omitted. The last output record contains 999999 in the first word of the record (record 5) and is followed by two consecutive end of file marks. If the program reaches the end of reel marker on an output tape prior to the end of the output data, the program will write an end of

```
                         EXAMPLE LONG TERM PROBLEM                                                 DATE 040679, PAGE   15

                                                            TABLE    3

          SEASONAL GVOUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) DUE TO SOURCES        1
                                                            SEASON  1
                                                  - GRID SYSTEM X AXIS (METERS) -
                            (THE MAXIMUM CONCENTRATION IS       .3488480 AT X=   1000.0, Y=        0)
                 -3000.000    -2000.000    -1500.000    -1200.000    -1000.000     -800.000     -600.000     -400.000     -200.000
Y AXIS (METERS)                                                 -  CONCENTRATION  -
                 ------------------------------------------------------------------------------------------------------------

    3000.000      .0663080     .0714365     .0761680     .0910158     .1013271     .1117467     .1220519     .1320038     .1261425
    2000.000      .0658299     .1019243     .1028515     .1006472     .1171970     .1371107     .1577907     .1786755     .1681064
    1500.000      .0530633     .1073598     .1147369     .1072360     .1005035     .1196215     .1451903     .1729188     .1616255
    1200.000      .0419286     .0900507     .1162105     .1012587     .0889378     .0846204     .1085702     .1363996     .1280662
    1000.000      .0391882     .0747810     .0989019     .0917209     .0741645     .0574046     .0703985     .0933265     .0891247
     800.000      .0426437     .0569370     .0737071     .0737115     .0551636     .0345990     .0297793     .0429379     .0431686
     600.000      .0461110     .0469514     .0477459     .0426916     .0327306     .0149123     .0042631     .0079336     .0091713
     400.000      .0495345     .0501218     .0317220     .0184583     .0108352     .0038282     .0003500     .0001663     .0002176
     200.000      .0528574     .0533615     .0307146     .0113791     .0028852     .0003654     .0000177     .0000001     .0000004
        .000      .0560220     .0569906     .0312991     .0102307     .0020033     .0001372     .0000008     .0000000     .0000000
    -200.000      .0471526     .0437914     .0225019     .0072246     .0014780     .0000707     .0000006     .0000002     .0000003
    -400.000      .0382537     .0310111     .0141703     .0054381     .0021335     .0004251     .0002690     .0001260     .0002740
    -600.000      .0295048     .0184584     .0115697     .0073965     .0041936     .0036400     .0034103     .0050979     .0100161
    -800.000      .0210708     .0138798     .0132014     .0099070     .0100576     .0109922     .0164745     .0274969     .0412380
   -1000.000      .0130954     .0148946     .0150512     .0153900     .0173739     .0196544     .0376019     .0590125     .0768013
   -1200.000      .0097218     .0158339     .0174560     .0207404     .0234999     .0318820     .0573781     .0840768     .1012374
   -1500.000      .0104984     .0169554     .0217358     .0258190     .0290315     .0500013     .0753745     .1018907     .1150695
   -2000.000      .0113053     .0185953     .0241984     .0280982     .0431601     .0611116     .0800283     .0992730     .1065635
   -3000.000      .0117773     .0179304     .0242401     .0355510     .0437082     .0521756     .0607574     .0692350     .0715726

                                                  - GRID SYSTEM X AXIS (METERS) -
                            (THE MAXIMUM CONCENTRATION IS        3488480 AT X=   1000.0, Y=        0)
                      .000      200.000      400.000      600.000      800.000     1000.000     1200.000     1500.000     2000.000
Y AXIS (METERS)                                                 -  CONCENTRATION  -
                 ------------------------------------------------------------------------------------------------------------

    3000.000      .1147252     .1030791     .0914420     .0800318     .0690371     .0663259     .0696821     .0730138     .0747186
    2000.000      .1468954     .1258146     .1052467     .1056082     .1163948     .1239225     .1284453     .1304994     .1184288
    1500.000      .1380701     .1132658     .1249480     .1476502     .1639378     .1739574     .1761818     .1644138     .1412666
    1200.000      .1096608     .1079708     .1470681     .1784143     .2002183     .2027374     .1971674     .1835808     .1556426
    1000.000      .0789711     .1106217     .1593282     .1993588     .2139525     .2155314     .2107958     .1963356     .1651370
     800.000      .0477034     .1038670     .1654333     .2025458     .2208990     .2269138     .2237307     .2087178     .1814621
     600.000      .0267074     .0830858     .1458314     .1950550     .2250061     .2368813     .2401768     .2329436     .1992959
     400.000      .0069513     .0451611     .1165948     .1849413     .2400131     .2678044     .2741419     .2606153     .2170810
     200.000      .0003912     .0216928     .1081797     .2103533     .2779569     .3070292     .3096913     .2883651     .2341709
        .000      .0001401     .0223755     .1270951     .2487123     .3225546     .3488480     .3454618     .3148865     .2498570
    -200.000      .0007029     .0257462     .1086712     .2037878     .2669579     .2943249     .2969587     .2770541     .2260114
    -400.000      .0071336     .0430548     .1085427     .1680550     .2163783     .2418941     .2486990     .2382636     .2010010
    -600.000      .0293359     .0690915     .1211015     .1651153     .1904912     .1989678     .2022621     .2001222     .1757602
    -800.000      .0653433     .0993264     .1327930     .1610533     .1791107     .1844357     .1812813     .1677582     .1511334
   -1000.000      .0978236     .1213868     .1424346     .1573985     .1673956     .1701630     .1668363     .1551187     .1296552
   -1200.000      .1165624     .1316768     .1441122     .1523211     .1557579     .1561743     .1528294     .1427324     .1208977
   -1500.000      .1233840     .1302972     .1355781     .1386539     .1390142     .1369158     .1330473     .1251225     .1080631
   -2000.000      .1091534     .1105814     .1106230     .1105241     .1099144     .1080903     .1052370     .0996278     .0885619
```

FIGURE 4-4. Example listing of seasonal ground-level concentration for the winter season due to a single source.

```
                      EXAMPLE LONG TERM PROBLEM                                                      DATE 040679, PAGE   16

                                                        TABLE    3 (CONT)

              SEASONAL GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) DUE TO SOURCES       1
                                                        SEASON  1
                                                 - GRID SYSTEM X AXIS (METERS) -
                                  (THE MAXIMUM CONCENTRATION IS       .3488480 AT X=   1000.0, Y=        0)
                         .000       200.000      400.000      600.000      800.000     1000.000     1200.000     1500.000     2000.000
 Y AXIS (METERS)                                                  -  CONCENTRATION  -
          ---------------------------------------------------------------------------------------------------------------------

    -3000.000        .0715538     .0710932     .0701957     .0688464     .0671095     .0659119     .0651092     .0632935     .0591422


                                                 - GRID SYSTEM X AXIS (METERS) -
                                  (THE MAXIMUM CONCENTRATION IS       .3488480 AT X=   1000.0, Y=        0)
                     3000.000
 Y AXIS (METERS)                                                  -  CONCENTRATION  -
          ---------------------------------------------------------------------------------------------------------------------

     3000.000        .0668234
     2000.000        .0881329
     1500.000        .0999153
     1200.000        .1097215
     1000.000        .1175142
      800.000        .1253279
      600.000        .1330037
      400.000        .1403664
      200.000        .1472332
         .000        .1534254
     -200.000        .1432522
     -400.000        .1324864
     -600.000        .1213838
     -800.000        .1101951
    -1000.000        .0991512
    -1200.000        .0884524
    -1500.000        .0765907
    -2000.000        .0666015
    -3000.000        .0493372
```

FIGURE 4-4. (Continued)

```
                      EXAMPLE LONG TERM PROBLEM
                                                                                      DATE 040679, PAGE  17
                                             TABLE     3 (CONT)
          SEASONAL GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) DUE TO SOURCES        1
                                                          SEASON  1
                                                 *-* DISCRETE POINT RECEPTORS *-*
  X            Y               (THE MAXIMUM CONCENTRATION IS       .2992802 AT X=    800.0, Y=    100.0)
                    CONCENTRATION                 X          Y        CONCENTRATION          X          Y        CONCENTRATION
            ---------------------------------------------------------------------------------------------------------------------

  -800.0       700.0        .0238388          -600.0       700.0         .0139966         -400.0       700.0        .0218427
  -200.0       700.0        .0231872              .0       700.0         .0380520          200.0       700.0        .0952985
   400.0       700.0        .1594433           600.0       700.0         .1994131          800.0       700.0        .2232446
   800.0       500.0        .2264379           800.0       300.0         .2583124          800.0       100.0        .2992802
   800.0      -100.0        .2938989           800.0      -300.0         .2412665          800.0      -500.0        .1963080
   600.0      -500.0        .1664181           400.0      -500.0         .1147844          200.0      -500.0        .0550614
      .0      -500.0        .0158442          -200.0      -500.0         .0025927         -400.0      -500.0        .0011200
  -600.0      -500.0        .0012109          -800.0      -500.0         .0013791         -800.0      -300.0        .0001711
  -800.0      -100.0        .0000922          -800.0       100.0         .0001882         -800.0       300.0        .0012570
  -800.0       500.0        .0005138
```

FIGURE 4-4. (Continued)

```
                                    EXAMPLE LONG TERM PROBLEM
                                                                                           DATE 040679, PAGE   27
                                                        TABLE    7
                 ANNUAL GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) DUE TO SOURCES        1
                                                 - GRID SYSTEM X AXIS (METERS) -
                                  (THE MAXIMUM CONCENTRATION IS      .3342176 AT X=   1200.0, Y=        .0)
                      -3000.000     -2000.000     -1500.000     -1200.000     -1000.000      -800.000      -600.000      -400.000      -200.000
 Y AXIS (METERS)                                                    -  CONCENTRATION  -
               ---------------------------------------------------------------------------------------------------------------------------

    3000.000      .0657812      .0737233      .0789163      .0904639      .0983871      .1063170      .1140818      .1214976      .1164424
    2000.000      .0657909      .1009417      .1035580      .1026990      .1133582      .1304855      .1461447      .1619269      .1528754
    1500.000      .0544416      .1052333      .1131752      .1076861      .1025810      .1168817      .1361314      .1571387      .1472273
    1200.000      .0444598      .0900249      .1138111      .1019665      .0921955      .0886200      .1067348      .1281784      .1200416
    1000.000      .0435112      .0767212      .0987529      .0932971      .0791244      .0659232      .0760146      .0944262      .0887995
     800.000      .0498882      .0612506      .0771507      .0772721      .0618206      .0451682      .0416062      .0530419      .0500894
     600.000      .0564691      .0552712      .0550004      .0504722      .0405052      .0243466      .0151506      .0180293      .0161209
     400.000      .0631362      .0646290      .0441334      .0292205      .0197301      .0089996      .0037619      .0027525      .0017865
     200.000      .0697587      .0742851      .0504273      .0263093      .0117042      .0034850      .0002277      .0000013      .0000166
        .000      .0761969      .0843790      .0582473      .0297778      .0118134      .0018075      .0000092      .0000000      .0000000
    -200.000      .0685632      .0723518      .0485787      .0249584      .0108949      .0030110      .0001864      .0000009      .0000283
    -400.000      .0607697      .0607697      .0402924      .0231492      .0127456      .0048973      .0019004      .0029933      .0022366
    -600.000      .0529790      .0495161      .0380228      .0267091      .0174252      .0113844      .0083620      .0200272      .0215265
    -800.000      .0453428      .0443433      .0395151      .0310625      .0264575      .0228208      .0328460      .0603510      .0657141
   -1000.000      .0379958      .0431965      .0406693      .0375947      .0361367      .0346694      .0668578      .1075721      .1128587
   -1200.000      .0338091      .0417705      .0418298      .0434039      .0438635      .0540903      .0974003      .1432972      .1465764
   -1500.000      .0315504      .0391120      .0447705      .0484955      .0507299      .0841306      .1253994      .1686825      .1691839
   -2000.000      .0276830      .0369793      .0447198      .0493357      .0735792      .1025840      .1331161      .1641737      .1627841
   -3000.000      .0221724      .0314964      .0411923      .0600469      .0735844      .0875996      .1017786      .1157723      .1144319

                                                 - GRID SYSTEM X AXIS (METERS) -
                                  (THE MAXIMUM CONCENTRATION IS      .3342176 AT X=   1200.0, Y=        .0)
                          .000       200.000       400.000       600.000       800.000      1000.000      1200.000      1500.000      2000.000
 Y AXIS (METERS)                                                    -  CONCENTRATION  -
               ---------------------------------------------------------------------------------------------------------------------------

    3000.000      .1069709      .0972725      .0875448      .0779703      .0687079      .0664568      .0693217      .0720768      .0731815
    2000.000      .1354147      .1180513      .1010981      .1018861      .1114915      .1182070      .1222337      .1240045      .1187746
    1500.000      .1276886      .1089050      .1178735      .1380086      .1526735      .1618765      .1656450      .1630912      .1506029
    1200.000      .1038349      .1022907      .1359838      .1636042      .1833369      .1917565      .1937633      .1896071      .1719582
    1000.000      .0780662      .1039111      .1453696      .1804445      .2004265      .2102687      .2131777      .2081652      .1867561
     800.000      .0504797      .0968152      .1488153      .1885301      .2142675      .2282716      .2327064      .2270524      .2039455
     600.000      .0296387      .0769905      .1377807      .1904340      .2263899      .2457561      .2534836      .2498034      .2216136
     400.000      .0095662      .0494178      .1214323      .1909904      .2416743      .2696532      .2797169      .2735753      .2390123
     200.000      .0028611      .0318882      .1132931      .2033218      .2651951      .2969272      .3067185      .2971033      .2556606
        .000      .0010773      .0282085      .1230197      .2271452      .2948798      .3267957      .3342176      .3197260      .2710471
    -200.000      .0024859      .0272142      .1013626      .1855807      .2458202      .2785385      .2903952      .2842080      .2473362
    -400.000      .0131979      .0484943      .1037730      .1540275      .2025273      .2332932      .2476926      .2483371      .2226719
    -600.000      .0386556      .0820172      .1278737      .1646614      .1880384      .1987607      .2070426      .2132873      .1978455
    -800.000      .0736719      .1103873      .1482750      .1743903      .1892545      .1952096      .1941950      .1843081      .1735634
   -1000.000      .1105158      .1292880      .1560180      .1783572      .1884171      .1903857      .1874501      .1769500      .1525695
   -1200.000      .1374874      .1368074      .1559619      .1716981      .1829382      .1839524      .1796608      .1689052      .1460314
   -1500.000      .1555886      .1419866      .1450388      .1552728      .1624876      .1666003      .1663093      .1559194      .1356408
   -2000.000      .1500506      .1368667      .1234859      .1220501      .1268333      .1298098      .1311021      .1303337      .1179686
   -3000.000      .1076223      .1004349      .0930264      .0855490      .0781429      .0760634      .0779407      .0795573      .0795953
```

FIGURE 4-5. Example listing of annual ground-level concentration due to a single source.

```
                         EXAMPLE LONG TERM PROBLEM                                       DATE 040679, PAGE   28

                                                  TABLE    7 (CONT)

              ANNUAL GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) DUE TO SOURCES       1
                                                 - GRID SYSTEM X AXIS (METERS) -
                                (THE MAXIMUM CONCENTRATION IS       .3342176 AT X=   1200.0, Y=        0)
                     3000.000
Y AXIS (METERS)                                               -  CONCENTRATION  -
         --------------------------------------------------------------------------------------------------------

     3000.000       .0678604
     2000.000       .0989479
     1500.000       .1178334
     1200.000       .1307085
     1000.000       .1398141
      800.000       .1488980
      600.000       .1578026
      400.000       .1663583
      200.000       .1743915
         .000       .1817346
     -200.000       .1707091
     -400.000       .1590775
     -600.000       .1470861
     -800.000       .1349767
    -1000.000       .1229736
    -1200.000       .1112738
    -1500.000       .0986629
    -2000.000       .0891814
    -3000.000       .0709458


                                                *-* DISCRETE POINT RECEPTORS *-*
                                (THE MAXIMUM CONCENTRATION IS       .2790875 AT X=    800.0, Y=    100.0)
    X          Y      CONCENTRATION          X          Y      CONCENTRATION          X          Y      CONCENTRATION
         --------------------------------------------------------------------------------------------------------

  -800.0     700.0       .0344040        -600.0     700.0       .0265193        -400.0     700.0       .0335032
  -200.0     700.0       .0313295           0       700.0       .0409941         200.0     700.0       .0885098
   400.0     700.0       .1451861         600.0     700.0       .1899025         800.0     700.0       .2204819
   800.0     500.0       .2322350         800.0     300.0       .2528633         800.0     100.0       .2790875
   800.0    -100.0       .2694395         800.0    -300.0       .2236444         800.0    -500.0       .1871303
   600.0    -500.0       .1592000         400.0    -500.0       .1155917         200.0    -500.0       .0652046
      0     -500.0       .0237664        -200.0    -500.0       .0084338        -400.0    -500.0       .0088857
  -600.0    -500.0       .0043523        -800.0    -500.0       .0073524        -800.0    -300.0       .0037187
  -800.0    -100.0       .0022263        -800.0     100.0       .0024263        -800.0     300.0       .0051861
  -800.0     500.0       .0157196
```

FIGURE 4-5. (Continued)

```
                                   EXAMPLE LONG TERM PROBLEM
                                                                                               DATE 040679, PAGE   57
                                                                 TABLE   18
                    SEASONAL GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) DUE TO SOURCES        4     -6
                                                                SEASON  1
                                                      - GRID SYSTEM X AXIS (METERS) -
                                      (THE MAXIMUM CONCENTRATION IS     6.9718961 AT X=        .0, Y=     200.0)
                    -3000.000     -2000.000     -1500.000     -1200.000     -1000.000     -800.000     -600.000     -400.000     -200.000
 Y AXIS (METERS)                                                         - CONCENTRATION -
               ------------------------------------------------------------------------------------------------------------------------

   3000.000      .1141418      .1319421      .1454558      .1576181      .1646796      .1695634      .1799378      .1899483      .2029379
   2000.000      .1002635      .1965695      .2265424      .2487959      .2784030      .2994197      .3208302      .3343767      .3695897
   1500.000      .0883490      .1833633      .3001407      .3445785      .3742764      .4357218      .4807710      .5261769      .5685684
   1200.000      .0868473      .1740742      .2985061      .4219350      .4839304      .5526715      .6444270      .7255354      .8122584
   1000.000      .0782379      .1704902      .2796242      .4432822      .5581562      .6698401      .8122468      .9264829     1.0768082
    800.000      .0815178      .1734529      .2789948      .4138338      .5974831      .7800107     1.0254368     1.2259847     1.4632777
    600.000      .0874498      .1538142      .2921748      .4238053      .5741674      .9649034     1.2409456     1.7216658     2.0813136
    400.000      .0931038      .1602653      .2578091      .4267570      .6047384      .9960653     1.4172813     2.3158659     3.3261267
    200.000      .0985760      .1753029      .2669589      .3748579      .5348461      .8427733     1.4971163     3.1808350     5.7325077
       .000      .1060971      .1944830      .3044171      .4292693      .5629431      .7711754     1.2616232     2.4870587     2.1401007
   -200.000      .0862400      .1455983      .2118022      .2908234      .3549207      .4687632      .6623381     1.1127409     2.1681056
   -400.000      .0744033      .1161378      .1589985      .2058406      .2428107      .2866532      .3403045      .5583184     1.0531586
   -600.000      .0632915      .0902639      .1168941      .1256867      .1330589      .1681143      .2465926      .4086496      .6632069
   -800.000      .0523531      .0688757      .0686371      .0793848      .1079238      .1405344      .2107555      .3098069      .4821972
  -1000.000      .0421618      .0436945      .0524216      .0778494      .0978154      .1244069      .1793816      .2507580      .3667994
  -1200.000      .0338809      .0344636      .0517480      .0721187      .0848296      .1097387      .1528863      .2079439      .2844218
  -1500.000      .0205771      .0316304      .0495200      .0594711      .0703435      .0958984      .1256685      .1607275      .2049246
  -2000.000      .0180733      .0307280      .0388258      .0470829      .0611421      .0762805      .0933139      .1086355      .1333698
  -3000.000      .0164600      .0236835      .0308964      .0392882      .0452152      .0503179      .0563070      .0625100      .0714173

                                                      - GRID SYSTEM X AXIS (METERS) -
                                      (THE MAXIMUM CONCENTRATION IS     6.9718961 AT X=        .0, Y=     200.0)
                         .000       200.000       400.000       600.000       800.000     1000.000     1200.000     1500.000     2000.000
 Y AXIS (METERS)                                                         - CONCENTRATION -
               ------------------------------------------------------------------------------------------------------------------------

   3000.000      .2010357      .1899209      .1667694      .1496254      .1328521      .1200736      .1068011      .0905362      .0799768
   2000.000      .3672231      .3405232      .2831935      .2511466      .2175359      .1908647      .1653619      .1506803      .1472339
   1500.000      .5648663      .5165720      .4290459      .3620359      .3097311      .2592035      .2476832      .2423007      .1864903
   1200.000      .7804938      .7257326      .5783907      .4772948      .4012619      .3687351      .3539513      .2955036      .2181892
   1000.000     1.0168360      .9478712      .7253197      .6080014      .5191221      .4784085      .4276286      .3276516      .2541374
    800.000     1.4352105     1.2760890      .9683035      .8147290      .6816848      .5958496      .4811040      .3950513      .3084341
    600.000     2.1298606     1.8353405     1.4331974     1.1144136      .9000207      .7231802      .6284078      .5057603      .3124879
    400.000     3.6185203     3.1141638     2.1911772     1.5878779     1.2545607      .9881584      .7688218      .5181853      .3269650
    200.000     6.9718961     6.1562666     3.8886576     2.3056850     1.5077178     1.0451446      .7731910      .5474248      .3471881
       .000     4.2898535     4.2160221     5.0025682     2.7234529     1.7215330     1.2332151      .9253537      .6418082      .3944466
   -200.000     3.3432886     3.6495301     2.9721200     1.8854961     1.2606424      .8953713      .6752894      .4665176      .3144762
   -400.000     1.5517510     1.7295042     1.5100124     1.1879742      .9579759      .7684227      .6099996      .4255182      .2783940
   -600.000      .8974628      .9971198      .9477595      .7954105      .6534591      .5261887      .4652329      .3852223      .2496710
   -800.000      .6019226      .6679433      .6183227      .5774232      .5000733      .4297242      .3423477      .2831299      .2305795
  -1000.000      .4248233      .4816398      .4448333      .4211512      .3811153      .3503508      .3082802      .2313476      .1797784
  -1200.000      .3242385      .3566408      .3399289      .3194892      .2910321      .2738059      .2586550      .2112597      .1520373
  -1500.000      .2322335      .2437829      .2380929      .2289302      .2168897      .1920654      .1840825      .1763435      .1316120
  -2000.000      .1475033      .1529768      .1430510      .1426764      .1384300      .1331798      .1215424      .1114335      .1064191
```

FIGURE 4-6. Example listing of seasonal ground-level concentration for the winter season from combined sources.

```
                    EXAMPLE LONG TERM PROBLEM                                                  DATE 040679, PAGE   58

                                        TABLE   18 (CONT)

          SEASONAL GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) DUE TO SOURCES       4     -6
                                        SEASON  1
                                  - GRID SYSTEM X AXIS (METERS) -
                      (THE MAXIMUM CONCENTRATION IS     6 9718961 AT X=        0, Y=    200 0)
                  000       200 000      400 000      600 000      800 000     1000 000     1200 000     1500 000     2000 000
 Y AXIS (METERS)                                       -  CONCENTRATION  -
          ------------------------------------------------------------------------------------------------------------------

   -3000 000     0762889      0781394      0743938      0716538      0686034     .0680173      0665477      0631290      0576118


                                  - GRID SYSTEM X AXIS (METERS) -
                      (THE MAXIMUM CONCENTRATION IS     6 9718961 AT X=        0, Y=    200 0)
               3000 000
 Y AXIS (METERS)                                       -  CONCENTRATION  -
          ------------------------------------------------------------------------------------------------------------------

    3000 000     0733095
    2000 000     1039327
    1500 000     1255915
    1200 000    .1535645
    1000 000     1539334
     800 000     1599410
     600 000     1671212
     400 000    .1733707
     200 000    .1796219
         000     1968552
    -200 000     1664093
    -400 000     1533669
    -600 000     1413262
    -800 000     1288738
   -1000 000     1176781
   -1200 000     1112509
   -1500 000     0857681
   -2000 000     0719617
   -3000 000     0527143
```

FIGURE 4-6. (Continued)

```
                            EXAMPLE LONG TERM PROBLEM
                                                                                       DATE 040679, PAGE   59
                                                  TABLE   18 (CONT)
       SEASONAL GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) DUE TO SOURCES        4     -6
                                                  SEASON  1
                                         *-* DISCRETE POINT RECEPTORS *-*
                        (THE MAXIMUM CONCENTRATION IS     1 7364048 AT X=        0, Y=    700 0)
   X          Y       CONCENTRATION          X          Y       CONCENTRATION          X          Y       CONCENTRATION
        ------------------------------------------------------------------------------------------------------------

 -800 0      700 0       8117493         -600 0      700 0     1 1205399         -400 0      700 0     1 4398965
 -200 0      700 0     1 7271985              0      700 0     1 7364048          200 0      700 0     1 5022812
  400 0      700 0     1 1561680          600 0      700 0       9335419          800 0      700 0       7719783
  800 0      500 0     1 0299944          800 0      300 0     1 4238233          800 0      100 0     1 6112191
  800 0     -100 0     1 4909610          800 0     -300 0     1 1271033          800 0     -500 0       7590294
  600 0     -500 0       9355011          400 0     -500 0     1 1542949          200 0     -500 0     1 2878148
      0     -500 0     1 1525272         -200 0     -500 0       8228008         -400 0     -500 0       4641283
 -600 0     -500 0       2707720         -800 0     -500 0       2028217         -800 0     -300 0       3727635
 -800 0     -100 0       6205444         -800 0      100 0       7864283         -800 0      300 0       8847295
 -800 0      500 0       8593541
```

FIGURE 4-6. (Continued)

```
                          EXAMPLE LONG TERM PROBLEM                                                    DATE 040679, PAGE   69
                                                      TABLE   22
              ANNUAL GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) DUE TO SOURCES        4      -6
                                                 - GRID SYSTEM X AXIS (METERS) -
                              (THE MAXIMUM CONCENTRATION IS     7.2626314 AT X=      0., Y=    200.0)
                -3000.000    -2000.000    -1500.000    -1200.000    -1000.000    -800.000     -600.000     -400.000     -200.000
 Y AXIS (METERS)                                               -  CONCENTRATION  -
 ----------------------------------------------------------------------------------------------------------------------------

   3000.000      .1081413     .1273044     .1434386     .1583696     .1671300     .1732683     .1844741     .1953981     .2095746
   2000.000      .1015832     .1849181     .2127542     .2369587     .2688778     .2935262     .3183200     .3346033     .3717327
   1500.000      .0963382     .1783244     .2813926     .3217283     .3519249     .4161722     .4667258     .5175734     .5652893
   1200.000      .1023268     .1763367     .2854318     .3956212     .4519010     .5202100     .6157927     .7051040     .8008198
   1000.000      .0968009     .1807603     .2743777     .4206982     .5238561     .6273392     .7696197     .8927491    1.0558734
    800.000      .1018517     .1956732     .2865334     .4034734     .5685959     .7338402     .9668641    1.1716807    1.4253546
    600.000      .1092990     .1842914     .3210994     .4392124     .5697182     .8294047    1.1764429    1.6398245    2.0185259
    400.000      .1164230     .1954204     .3031613     .4751588     .6480183     .9187334    1.3863701    2.2288543    3.2286666
    200.000      .1236696     .2150039     .3236190     .4493670     .6228654     .9435849    1.5977625    3.2179825    5.6923841
       .000      .1369063     .2483750     .3882477     .5487089     .7220800     .9944199    1.6074509    3.0923625    2.6428576
   -200.000      .1157676     .1978214     .2934413     .3983108     .5209506     .7237161    1.0813574    1.9102821    3.6460410
   -400.000      .1044182     .1697725     .2469949     .3457683     .4317395     .5415619     .6911927    1.0859942    1.8490452
   -600.000      .0937429     .1466207     .2161948     .2576480     .2941426     .3794517     .5196084     .7747602    1.1368915
   -800.000      .0830017     .1316911     .1568202     .1927340     .2519755     .3082290     .4174575     .5636082     .8182525
  -1000.000      .0734057     .1017166     .1316324     .1840005     .2181509     .2566793     .3372903     .4438984     .6193300
  -1200.000      .0679723     .0883285     .1271223     .1638574     .1807527     .2143712     .2788502     .3637273     .4798864
  -1500.000      .0523963     .0817971     .1160385     .1269854     .1398679     .1780526     .2225417     .2777672     .3459183
  -2000.000      .0483776     .0758405     .0830726     .0938818     .1129093     .1348580     .1615675     .1867826     .2271603
  -3000.000      .0436008     .0492403     .0566670     .0681799     .0773684     .0860592     .0970767     .1083919     .1235241

                                                 - GRID SYSTEM X AXIS (METERS) -
                              (THE MAXIMUM CONCENTRATION IS     7.2626314 AT X=      0., Y=    200.0)
                     .000      200.000      400.000      600.000      800.000     1000.000     1200.000     1500.000     2000.000
 Y AXIS (METERS)                                               -  CONCENTRATION  -
 ----------------------------------------------------------------------------------------------------------------------------

   3000.000      .2084212     .1975875     .1740339     .1564915     .1393119     .1268104     .1141896     .0994846     .0914290
   2000.000      .3712415     .3460417     .2893914     .2589800     .2274956     .2034184     .1796961     .1674393     .1726839
   1500.000      .5651725     .5204625     .4378076     .3754549     .3277997     .2799759     .2735982     .2776494     .2259505
   1200.000      .7776147     .7306131     .5929082     .4995674     .4313213     .4082952     .4020353     .3482466     .2686575
   1000.000     1.0111198     .9556264     .7475902     .6449546     .5705478     .5417362     .4965507     .3938842     .3218361
    800.000     1.4247020    1.2928320    1.0126968     .8858870     .7712021     .6919558     .5738645     .4913236     .4101755
    600.000     2.1113196    1.8808085    1.5367937    1.2515395    1.0534037     .8811789     .7946158     .6657851     .4368843
    400.000     3.6187124    3.2515676    2.4588448    1.9104816    1.5904107    1.2948685    1.0327690     .7221396     .4750164
    200.000     7.2626314    6.7969908    4.8092940    3.0427486    2.0599341    1.4657391    1.1062136     .7973575     .5209101
       .000     5.7629929    5.9654953    7.1137160    3.9463701    2.5282444    1.9248926    1.3790720     .9675695     .6095494
   -200.000     5.4172053    5.7465124    4.5743911    2.8867406    1.9297234    1.3676705    1.0325982     .7506633     .4964318
   -400.000     2.5369104    2.7341756    2.3556986    1.8604320    1.4948735    1.1928056     .9424827     .6575294     .4387487
   -600.000     1.4530077    1.5667025    1.4838248    1.2576386    1.0415857     .9353440     .7324626     .6018294     .3928246
   -800.000      .9757536    1.0491882     .9601682     .9086269     .8009534     .6954852     .5531519     .4524232     .3666116
  -1000.000      .6889211     .7548569     .6838968     .6536332     .6079808     .5701869     .5068222     .3801297     .2917370
  -1200.000      .5287903     .5621441     .5219476     .4911611     .4577811     .4444123     .4284611     .3543340     .2532897
  -1500.000      .3825202     .3870242     .3659147     .3478544     .3343780     .3060275     .3039352     .3012857     .2283927
  -2000.000      .2464945     .2484366     .2242978     .2183107     .2108029     .2066464     .1951130     .1896241     .1930840
  -3000.000      .1306498     .1315433     .1226095     .1155300     .1081912     .1061195     .1044181     .1032138     .1033750
```

FIGURE 4-7. Example listing of annual ground-level concentration from combined sources.

```
                         EXAMPLE LONG TERM PROBLEM                                             DATE 040679, PAGE   70

                                            TABLE   22 (CONT)

              ANNUAL GROUND LEVEL CONCENTRATION (MICROGRAMS/CUBIC METER) DUE TO SOURCES        4     -6
                                               - GRID SYSTEM X AXIS (METERS) -
                         (THE MAXIMUM CONCENTRATION IS     7 2626314 AT X=        0, Y=    200 0)
                3000 000
 Y AXIS (METERS)                                  -  CONCENTRATION  -
          ---------------------------------------------------------------------------------------------------------

   3000 000       0907452
   2000 000       1329369
   1500 000       1636009
   1200 000       2114492
   1000 000       2209766
    800 000       2372937
    600 000       2552890
    400 000       2723675
    200 000       2899689
        000       3256767
   -200 000       2806198
   -400 000       2582361
   -600 000       2371091
   -800 000       2154627
  -1000 000       1963955
  -1200 000       1873360
  -1500 000       1484415
  -2000 000       1323896
  -3000 000       1073769


                                               *-* DISCRETE POINT RECEPTORS *-*
                            (THE MAXIMUM CONCENTRATION IS     2 2940555 AT X=    800 0, Y=    100 0)
   X           Y       CONCENTRATION          X           Y       CONCENTRATION          X           Y       CONCENTRATION
          ---------------------------------------------------------------------------------------------------------

  -800 0     700 0        7695545          -600 0       700 0     1 0576697          -400 0       700 0     1 3721820
  -200 0     700 0      1 6771735              0        700 0     1 7224656           200 0       700 0     1 5260008
   400 0     700 0      1 2210786           600 0       700 0     1 0287999           800 0       700 0       8865934
   800 0     500 0      1 2490251           800 0       300 0     1 8757826           800 0       100 0     2 2940555
   800 0    -100 0      2 2237931           800 0      -300 0     1 7456491           800 0      -500 0     1 1984510
   600 0    -500 0      1 4739595           400 0      -500 0     1 8034916           200 0      -500 0     2 0276574
       0    -500 0      1 8698347          -200 0      -500 0     1 4235151          -400 0      -500 0       8962560
  -600 0    -500 0        5758534          -800 0      -500 0       4309813          -800 0      -300 0       6384920
  -800 0    -100 0        8572147          -800 0       100 0       9532369          -800 0       300 0       9456299
  -800 0     500 0        8464675
```

FIGURE 4-7. (Continued)

TABLE 4-6

LONGZ INPUT/OUTPUT TAPE FORMAT

Tape Logical Record	Word Number	Parameter Name	Integer (I)/ Floating Point (FP)
1	1	NXPNTS	I
	2	NYPNTS	I
	3	NSEASN	I
	4	NSPEED	I
	5	NSTBLE	I
	6	NSCTOR	I
	7	NXWYPT	I
	8-27	TITLE	I
	28-33	LUNT	I
	34-36	LKNT	I
	37	NSORY	I
	38-57	ISW	I
	58	IOVRSN	I
2	1 - NXPNTS	X (X-axis)	FP
	NXPNTS+1 - NXPNTS+NYPNTS	Y (Y-axis)	FP
	NXPNTS+NYPNTS+1 - NXPNTS+NYPNTS+ NXWYPT	X (discrete)	FP
	NXPNTS+NYPNTS+ NXWYPT+1 - NXPNTS+NYPNTS+ 2*NXWYPT	Y (discrete)	FP
3	1 - NXPNTS*NYPNTS +NXWYPT	Z	FP
4	1	TK	FP
	2-37	SIGEPU	FP
	38-73	SIGEPL	FP
	74	G	FP
	75-98	TA	FP

TABLE 4-6 (Continued)

Tape Logical Record	Word Number	Parameter Name	Integer (I)/ Floating Point (FP)
4 (Cont.)	99-242	HM	FP
	243-278	DPDZ	FP
	279-294	THETA	FP
	295-300	UBAR	FP
	301-2604	FREQ	FP
	2605-2640	P	FP
	2641	ZR	FP
	2642	GAMMA1	FP
	2643	GAMMA2	FP
	2644	ROTATE	FP
	2645	DECAY	FP
	2646	HA	FP
	2647	UTMX	FP
	2648	UTMY	FP
5*	1	NUMSQ2	I
	2	TYPE2	I
	3-146	QSS2	FP
	147	DX2	FP
	148	DY2	FP
	149	H2	FP
	150	TS2	FP
	151	VOL2	FP
	152	RDS2	FP
	153	NVS2	FP
	154-173	VS2	FP
	174-193	FRQ2	FP
	194-195	DATE2	I

*Records 5 through 9 are repeated for each source input to the program.

TABLE 4-6 (Continued)

Tape Logical Record	Word Number	Parameter Name	Integer (I)/ Floating Point (FP)
5* (Cont.)	196 197	HS2 NBX2	FP I
6**	1 - NXPNTS*NYPNTS +NXWYPT	CON	FP
7**	1 - NXPNTS*NYPNTS +NXWYPT	CON	FP
8**	1 - NXPNTS*NYPNTS +NXWYPT	CON	FP
9**	1 - NXPNTS*NYPNTS +NXWYPT	CON	FP
⋮	⋮	⋮	
last	1	999999	I

*Records 5 through 9 are repeated for each source input to the program.

**Records 6 through 9 are concentration calculations for each season and 7 through 9 are omitted if the input data is annual.

file mark, an end of tape sentinel record and two more end of file marks and then go to the next specified output tape reel. The end of tape sentinel record consists of 14 UNIVAC 1110 words, with the first word of the record equal to an octal 541600000000 and all other words in the record equal to zero. See Section 4.2.2 for the correct tape assign cards.

4.2.5 Program Run Time, Page and Tape Output Estimates

This section gives approximations to the computer run time, tape output and page output for the LONGZ program. Because of the variability of problem runs and input parameters, the equations in this section are meant only to give an approximation of the time, page and/or tape usage function.

a. Run Time. The total run time required for a problem run for the long-term (LONGZ) program is given by

$$\text{Time (Seconds)} \simeq \left\{ \left[N_s \cdot (N_x \cdot N_y + N_{xy}) \cdot N_{se} \cdot N_{st} \cdot N_{sp} \right] \cdot f + \left[(I + J + K) \cdot (N_x \cdot N_y + N_{xy}) \cdot N_{se} \right] \cdot g \right\} \geq 120 \qquad (4\text{-}2)$$

where

N_s = the total number of sources (card + tape) for which concentration calculations are to be made

N_x = the total number of points in the grid system X-axis, NXPNTS

N_y = the total number of points in the grid system Y-axis, NYPNTS

N_{xy} = the total number of discrete (arbitrarily placed) points, NXWYPT

N_{se} = the number of seasons, NSEASN

N_{st} = the number of stability categories, NSTBLE

N_{sp} = the number of wind speed categories, NSPEED

I = the number of sources read from an input tape

J = the number of sources written to an output tape

K = the summation of the total number of sources in each source combination printed. For example, if NGROUP were equal to "4" and three sources were combined for the first group, ten for the second, thirteen for the third and twenty-six for the fourth group, then K would be equal to 52

f = 1.5×10^{-3}

g = 2.2×10^{-3}

The constants f and g have been calculated from example runs on a UNIVAC 1108 computer. If the values of f and g given here are not accurate for your runs, recalculate and replace them with more representative values.

b. Page Output. The total number of pages of output from the long-term LONGZ program depends on the problem being run and is given by:

$$\text{Pages} \quad \underline{A} + \underline{B} + \underline{C} \tag{4-3}$$

where*

$$\underline{A} = \left\{ 15 \cdot I + \left[\frac{N_{sc}}{44}\right] \cdot J + \left[\frac{N_{st}}{44}\right] \cdot K + \left[\frac{N_{sc} + N_{st}}{44}\right] \cdot L \right.$$
$$\left. + M \cdot \left(\left[\frac{N_x}{9}\right] \cdot \left[\frac{N_y}{38}\right] + \left[\frac{N_{xy}}{129}\right] \right) \right\} \tag{4-4}$$

---

*The [ ] symbols indicate to round up to the next larger integer if there is any fractional part.

where

$$I = \begin{cases} 1 & ; \text{ if } ISW(5) > 0 \\ 0 & ; \text{ if } ISW(5) = 0 \end{cases}$$

$$J = \begin{cases} 1 & ; \text{ if } ISW(5) > 0 \\ 0 & ; \text{ if } ISW(6) = 0 \end{cases}$$

$$K = \begin{cases} 1 & ; \text{ if } ISW(7) > 0 \\ 0 & ; \text{ if } ISW(7) = 0 \end{cases}$$

$$L = \begin{cases} 1 & ; \text{ if } ISW(2) = 2 \\ 0 & ; \text{ if } ISW(2) \neq 2 \end{cases}$$

$$M = \begin{cases} 1 & ; \text{ if } ISW(8) > 0 \text{ and } ISW(5) > 0 \\ 0 & ; \text{ if } ISW(8) = 0 \text{ or } ISW(5) = 0 \end{cases}$$

N_{sc} = total number of sources input via data card (NSOURC)

N_{st} = total number of sources input via tape

$$\underline{B} \cong I \cdot N_c \cdot \left(\left[\frac{N_x}{9} \right] \cdot \left[\frac{N_y}{38} \right] + \left[\frac{N_{xy}}{129} \right] \right) \qquad (4\text{-}5)$$

I = number of seasons for which concentration is to be printed. If seasonal output only, then I=NSEASN; if annual output only, then I=1; if both seasonal and annual output, then I=NSEASN+1.

N_c = total number of combined source concentration tables being printed (NGROUP).

N_x = NXPNTS

N_y = NYPNTS

N_{xy} = NXWYPT

$C \cong$ the number of pages expected from the system plus other processing within the job

The above equations may not cover every option in the LONGZ program and, if the system the user is using aborts runs that max-page, be generous with the page approximation.

c. Tape Output. The total amount of tape used by a problem run depends on the number of sources, whether seasonal or annual data are being used and the size of the receptor arrays. This section provides the user with an approximation to the tape length used in feet.

The total number of computer words output to tape is given by

$$\text{Words} = \Big(2692 + N_x + N_y + 2N_{xy} + N_s \big(196 + N_{se}(N_x \cdot N_y + N_{xy})\big)\Big) \tag{4-6}$$

where

N_s = the total number of sources output to tape

N_{se} = the number of seasons, NSEASN

N_x = NXPNTS

N_y = NYPNTS

N_{xy} = NXWYPT

The user can approximate the length of tape required by

$$\text{Length (feet)} \cong \left(\left(\frac{\text{Words} \cdot 36}{B_y \cdot D}\right) + 0.75\left(\frac{\text{Words}}{2000}\right) + 6.0\right) / 12.0 \qquad (4\text{-}7)$$

where

B = the number of bits per computer word (UNIVAC 1110 is 36)

D = the tape recording density chosen by the user or required by the I/O device, 200, 556, 800 or 1600 bpi

B_y = "6" for 7-track tape or "8" for 9-track tape

The values 0.75 and 6.0 inches are used assuming the interrecord gap is 0.75 and the end of file is 6 inches.

4.2.6 Program Diagnostic Messages

The diagnostic messages produced by the LONGZ program are associated only with data and processing errors within the program and should not be confused with those produced by the computer system on which the LONGZ program is run. WARNING messages could indicate data errors and should be examined thoroughly when they occur. A list of the messages are given in Table 4-7 with the probably cause of the respective message.

TABLE 4-7

LONGZ WARNING AND ERROR MESSAGES

1. ***WARNING - TAPE SOURCE n NOT FOUND - INPUT CARD SOURCE IGNORED, DISP = m.
   The user has specified an input card source ID-number with a disposition code DISP that requires an incoming tape source. The program has been unable to locate the corresponding tape source.

2. WARNING - FREQ. DIST. IS NOT 1.0 FOR SEASON n, PROG NORMALIZES BY FACTOR xxx.x.
   The sum over all categories of the joint frequency of occurrence of wind speed and wind direction for season n is not exactly 1.0 and the program normalizes the frequency distribution by the factor xxx.x; execution continues.

3. **ERROR INPUT TAPE RECORD n.
   The program has encountered an unrecoverable input error at tape record n. Check the accounting sheet or the system log device for the system error code.

4. **ERROR OUTPUT TAPE RECORD n.
   The program has encountered an unrecoverable output error at tape record n. Check the accounting sheet or the system log device for the system error code.

5. *WARNING Z > HM+HA, SOURCE i, SEASON j, STABILITY k, SPEED ℓ, X = xxxx.x, Y = xxx.x.
   The terrain elevation exceeds the mixing layer elevation for this combination of source, season, stability and wind speed.

6. - END-FILE, RECORD n, INPUT TAPE.
   The program has encountered an end of file at n on the input tape.

TABLE 4-7 (Continued)

7. TOO MANY WARNING MESSAGES PROG STOPS PRINTING THEM.
   The program stops printing warning messages 5 above after 50 of these messages are printed.

8. ***READ ERROR ON UNIT n AT RECORD m.
   The program has encountered an unrecoverable tape read error. Check the accounting sheet or system log for the error code.

9. ***END OF DATA ON UNIT n, m RECORDS READ.
   Normal termination of input data.

10. ***END OF FILE ON UNIT n, m RECORDS READ.
    Normal end of file on input data.

11. ***WARNING - MORE INPUT REELS THAN UNITS ASSIGNED PROG. GOING TO FIRST UNIT ASSIGNED.
    The user has specified more tape reels NINTP or NOTTP than have been specified in the array NINFL or NOTFL. The program assumes the user has directed the operator to mount additional tape reels beginning with the first specified logical unit (NINFL(1) or NOTFL(1)).

12. ***END OF OUTPUT REEL ON UNIT n, RECORDS m THROUGH ℓ WRITTEN.
    The program has filled a tape reel, written the end of tape sentinel record and is going to the next output reel.

13. ***END OF OUTPUT DATA ON UNIT n, RECORDS m THROUGH ℓ WRITTEN, xxxx FEET OF TAPE USED.
    Message to inform the user that the last of the source/concentration inventory has been written to tape and giving the amount of tape used in feet.

TABLE 4-7 (Continued)

14. ***WARNING - NOT ENOUGH ROOM ON REEL ON UNIT n, PROG. STARTS FIRST OUPUT REC. ON NEXT REEL.

There is not enough room on the first output reel to place the first record and end of tape sentinel information, so the program goes to the next sequential output reel.

15. @ASG, T nnnnnnnnnnnn., F/ii/POS/ii
@USE 12, nnnnnnnnnnnn.
MASS STORAGE CSF$ REQUEST REJECTED,
STATUS = 000000000000,
TRIED j TIMES

The program has attempted to assign mass storage unit 12 and has failed. Check the FAC status bits to determine the cause of the error.

16. **WARNING - COMPLEX TERRAIN SWITCH SET WITH DEPOSITION (NVS1), COMPLEX TERRAIN IGNORED

The user has attempted to calculate concentration with deposition occurring while using terrain elevation data. The LONGZ program discards the terrain data for all calculations.

17. **ERROR - USING COMPLEX TERRAIN WITH DEPOSITION (NVS1) AND NOT FIRST SOURCE

The LONGZ program attempts to discard all terrain data when concentration with deposition occurring is being calculated. However, the first source input did not have NVS1 set and the program allowed invalid calculations for that source. If you have terrain data in the data set and deposition is occurring, the first source input (from card or tape) must have NVS1 set greater than zero.

REFERENCES

Benkley, C. W. and L. L. Schulman, 1979: Estimating hourly mixing depths from historical meteorological data. Journal of Applied Meteorology, 18, 772-780.

Bigg, E. K., G. P. Ayers and D. E. Turvey, 1978: Measurement of the dispersion of a smoke plume at large distances from the source. Atmospheric Environment, 12, 1815-1818.

Bjorklund, J. R. and J. F. Bowers, 1979: User's instructions for the SHORTZ and LONGZ computer programs. H. E. Cramer Company, Inc. Technical Report TR-79-131-01, H. E. Cramer Company, Inc., Salt Lake City, UT.

Bowers, J. F. and H. E. Cramer, 1976: Comparison of calculated and observed charateristics of plumes from two coal-fired power plants located in complex terrain. Preprint Volume for the Third Symposium on Atmospheric Turbulence, Diffusion and Air Quality, American Meteorological Society, Boston, MA.

Bowers, J. F., J. R. Bjorklund and C. S. Cheney, 1979: Industrial Source Complex (ISC) Dispersion Model user's guide. EPA Reports EPA-450/4-79-030 and EPA-450/4-79-031 (NTIS Accession Numbers PB80-133044 and PB80-133051), U. S. Environmental Protection Agency, Research Triangle Park, NC.

Bowers, J. F. and A. J. Anderson, 1981: An evaluation study for the Industrial Source Complex (ISC) Dispersion Model. EPA Report No. EPA- 450/4-81-002 (NTIS Accession No. PB81-176539), U. S. Environmental Protection Agency, Research Triangle Park, NC.

Briggs, G. A., 1969: Plume Rise. Available as TID-25075 from Clearinghouse for Federal Scientific and Technical Information, Springfield, VA, 80.

Briggs, G. A., 1971: Some recent analyses of plume rise observations. In Proceedings of the Second International Clean Air Congress, Academic Press, NY.

Briggs, G. A., 1972: Chimney plumes in neutral and stable surroundings. Atmospheric Environment, 6(7), 507-510.

Briggs, G. A., 1975: Plume rise predictions. Lectures on Air Pollution and Environmental Impact Analyses, American Meteorological Society, Boston, MA.

Brownlee, K. A., 1965: Statistical Theory and Methodology in Science and Engineering. John Wiley and Sons, NY.

REFERENCES (Continued)

Calder, K. L., 1971: A climatological model for multiple source urban air pollution. Proceedings 2nd Meeting of the Expert Panel on Air Pollution Modeling, NATO Committee on the Challenges of Modern Society, Paris, France, July 1971, 33.

Cramer, H. E., 1957: A practical method for estimating the disperal of atmospheric contaminants. Proceedings of the First National Conference on Applied Meteorology, American Meteorological Society, C-33 to C-55.

Cramer, H. E., et al., 1972: Development of dosage models and concepts. Final Report under Contract DAAD09-67-C-0020(R) with the U. S. Army, Deseret Test Center Report DTC-TR-72-609, Fort Douglas, UT.

Cramer, H. E., H. V. Geary and J. F. Bowers, 1975: Diffusion-model calculations of long-term and short-term ground-level SO_2 concentrations in Allegheny County, Pennsylvania. EPA Report 903/9-75-018 (NTIS Accession No. PB-245262/AS), U. S. Environmental Protection Agency, Region III, Philadelphia, PA.

Cramer, H. E., 1976: Improved Techniques for modeling the dispersion of tall stack plumes. Proceedings 7th Meeting of the Expert Panel on Air Pollution Modeling, NATO Committee on the Challenges of Modern Society, Arlie, Virginia, September 1976, 731-780.

Cramer, H. E. and J. F. Bowers, 1976: Assessment of the air quality impact of emissions from the Emery and Huntington Power Plants. H. E. Cramer Company, Inc. Technical Report TR-76-114-01 prepared for U. S. Department of Interior, Bureau of Land Management, Denver, CO.

Cramer, H. E., J. F. Bowers and H. V. Geary, 1976: Assessment of the air quality impact of SO_2 emissions from the ASARCO-Tacoma smelter. EPA Report No. EPA 910/9-76-028, U. S. Environmental Protection Agency, Region X, Seattle, WA.

DeMarrais, G. A., 1959: Wind speed profiles at Brookhaven National Laboratory. Journal of Meteorology, 16, 181-190.

Draxler, R., 1979: A summary of recent atmospheric diffusion experiments. NOAA Technical Memorandum EAL ARL-78, Air Resources Laboratories, Silver Spring, MD.

Environmental Protection Agency, 1969: Air Quality Display Model. Prepared by TRW Systems Group, Washington, D. C., available as PB 189-194 from the National Technical Information Service, Springfield, VA.

REFERENCES (Continued)

Environmental Protection Agency, 1977: User's manual for the Single Source (CRSTER) Model. *EPA Report No. EPA-450/2-77-013*, U. S. Environmental Protection Agency, Research Triangle Park, NC.

Environmental Protection Agency, 1978: Technical support document for determination of good engineering practice stack height. *Draft EPA OAQPS Report*, U. S. Environmental Protection Agency, Research Triangle Park, NC.

Hanna, S. R., *et al.*, 1977: AMS Workshop on Stability Classification Schemes and Sigma Curves - Summary of recommendations. *Bulletin American Meteorological Society*, *58*(12), 1305-1309.

Holzworth, G. C., 1972: Mixing heights, wind speeds and potential for urban air pollution throughout the contiguous United States. *Publication No. AP-101*, U. S. Environmental Protection Agency, Research Triangle Park, NC.

Huber, A. H. and W. H. Snyder, 1976: Building wake effects on short-stack effluents. *Preprint Volume for the Third Symposium on Atmospheric Turbulence, Diffusion and Air Quality*, American Meteorological Society, Boston, MA.

Irwin, J. S., 1979: Estimating plume dispersion--a recommended generalized scheme. *Preprint Volume for the Fourth Symposium on Turbulence, Diffusion and Air Pollution*, American Meteorological Society, Boston, MA.

Luna, R. E. and H. W. Church, 1972: A comparison of turbulence intensity and stability ratio measurements to Pasquill stability classes. *Journal of Applied Meteorology*, *11*(4), 663-669.

McDonald, J. E., 1960: An aid to computation of terminal fall velocities of spheres. *Journal of Meteorology*, *17*, 463.

Osipov, Y. S., 1972: Diffusion from a point source of finite time of action. In *AICE Survey of USSR Air Pollution Literature - Volume XII*, distributed by National Technical Information Service, Springfield, VA.

Pasquill, F., 1961: The estimation of the dispersion of windborne material. *Meteorology Magazine*, *90*, 33-49.

Pasquill F., 1974: *Atmospheric Diffusion (Second Edition)*. Ellis Horwood Limited, Sussex, England, 429.

Plate, E. J. and A. A. Quraishi, 1965: Modeling of velocity distribution inside and above tall crops. *Journal of Air Pollution Control Association*, *27*(9), 863-866.

REFERENCES (Continued)

Schulman, L. L. and J. S. Scire, 1980: Development of an air quality dispersion model for aluminum reduction plants. Environmental Research and Technology, Inc. Document P-7304A prepared for the Aluminum Association, Inc., Washington, D.C.

Touma, J. S., 1977: Dependence of the wind profile power law on stability for various locations. Journal of Air Pollution Control Association, 27(9), 863-866.

Turner, D. B., 1964: A diffusion model for an urban area. Journal of Applied Meteorology, 3(1), 83-91.

Turner, D. B., 1969: Workbook of Atmospheric Dispersion Estimates, PHS Publication No. 999-AP-26, U. S. Dept. of Health, Education and Welfare, National Air Pollution Control Administration, Cincinnati, OH.

Yamamoto, S. and O. Yokoyama, 1974: A practical method for estimating the dispersion of plumes. Journal of Japan Soc. Air Pollution, 9(2), 287.